S. HRG. 107–1021

AERONAUTICAL RESEARCH AT NASA

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED SEVENTH CONGRESS

FIRST SESSION

APRIL 24, 2001

Printed for the use of the Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE

88–462 PDF WASHINGTON : 2003

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2250 Mail: Stop SSOP, Washington, DC 20402–0001

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED SEVENTH CONGRESS

FIRST SESSION

JOHN McCAIN, Arizona, *Chairman*

TED STEVENS, Alaska
CONRAD BURNS, Montana
TRENT LOTT, Mississippi
KAY BAILEY HUTCHISON, Texas
OLYMPIA J. SNOWE, Maine
SAM BROWNBACK, Kansas
GORDON SMITH, Oregon
PETER G. FITZGERALD, Illinois
JOHN ENSIGN, Nevada
GEORGE ALLEN, Virginia

ERNEST F. HOLLINGS, South Carolina
DANIEL K. INOUYE, Hawaii
JOHN D. ROCKEFELLER IV, West Virginia
JOHN F. KERRY, Massachusetts
JOHN B. BREAUX, Louisiana
BYRON L. DORGAN, North Dakota
RON WYDEN, Oregon
MAX CLELAND, Georgia
BARBARA BOXER, California
JOHN EDWARDS, North Carolina
JEAN CARNAHAN, Missouri

MARK BUSE, *Republican Staff Director*
ANN CHOINIERE, *Republican General Counsel*
KEVIN D. KAYES, *Democratic Staff Director*
MOSES BOYD, *Democratic Chief Counsel*

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

GEORGE ALLEN, Virginia, *Chairman*

TED STEVENS, Alaska
CONRAD BURNS, Montana
TRENT LOTT, Mississippi
KAY BAILEY HUTCHISON, Texas
SAM BROWNBACK, Kansas
PETER G. FITZGERALD, Illinois

JOHN B. BREAUX, Louisiana
JOHN D. ROCKEFELLER IV, West Virginia
JOHN F. KERRY, Massachusetts
BYRON L. DORGAN, North Dakota
MAX CLELAND, Georgia
JOHN EDWARDS, North Carolina
JEAN CARNAHAN, Missouri

CONTENTS

AERONAUTICAL RESEARCH AT NASA

TUESDAY, APRIL 24, 2001

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:33 p.m., in room SR–253, Russell Senate Office Building, Hon. George Allen, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. GEORGE ALLEN, U.S. SENATOR FROM VIRGINIA

Senator ALLEN. The Science, Technology, and Space Subcommittee will come to order. We have a hearing today, and I especially want to welcome our esteemed and knowledgeable guests that we have here today, including some from the House and Senate, and obviously leaders in the areas of aeronautics which is the main focus of this hearing.

The purpose of this Subcommittee hearing is to examine the technologies which are so essential for our scientific, economic, and technical competitiveness of the United States insofar as aeronautics is concerned.

This is my first chairmanship of this Subcommittee, and I do want to thank Senator Brownback for yielding this chairmanship to me. I am pleased to be joined by the Ranking Member, Senator Breaux of Louisiana, as well as Senator Rockefeller of West Virginia, and my esteemed colleague from the Commonwealth of Virginia, Senator Warner, all of whom I am sure will have some remarks.

I am very pleased to be a part of this and the chair of this Subcommittee. We worked a great deal while I was Governor on technology, and we had unprecedented growth in technology jobs in Virginia, in Northern Virginia obviously, in the Richmond area with Infineon Technologies, and Gateway Computers in the Hampton area, but also part of all of that was the fortunate marriage of the efforts of NASA-Langley and how that helps in the spinoff of jobs and indirect jobs, thanks to them.

Now, before we proceed with this particular hearing, I would like to lay out to my colleagues some of the agenda that I see coming forward in this Subcommittee throughout the next year-and-a-half.

Senator Brownback will chair two Subcommittee hearings, given his deep and abiding interest in certain areas. The first issue is carbon sinks and global warming, and the second is human cloning.

We will be working with Senator Brownback on all of these important issues.

I also would say to my colleagues on this Subcommittee, should you all have any particular ideas that you think are important and that need to be addressed through a hearing, please let us know. We want to make sure that science and technology and space are not partisan issues. I think we all realize how important they are to the competitiveness of our country and advancements therein.

Some of the issues that I do think we will have hearings on will be the potential for new technologies to address some of the problems concerning military voter disenfranchisement, which was certainly made clear in the last election. I know there are Members of this Subcommittee, including Chairman McCain, who are looking for some reasonable solutions where technology can actually help our military folks overseas vote in our elections.

We will also have the NASA reauthorization bill before us next year, and in the intervening period, I would like to explore the balance between the aeronautical programs, the unmanned space missions, and the manned space missions, and determine which are the most beneficial and which may need some added boosters from the Subcommittee as well as the full Committee.

Other issues that may arise in this Subcommittee somewhat converge with those of some of the Members here who are on the Senate Republican High-Tech Task Force, issues such as the user fee diversion at the Patent and Trademark Office and the impact that this has on the ability of PTO to issue new patents for new technologies and inventions and innovations in a prompt way.

There will probably be some concern about intellectual property protection overseas, in particular, or the lack thereof and how that impacts our technologies and enterprises in this country, privacy rules and regulations promulgated overseas, especially in Europe and the impact that those regulations may have on domestic technological market development.

Also, I am sure that we will all be looking at the appropriate level of funding for the National Science Foundation. I believe every single Member here voted for the increased funding by putting it on a glidepath to eventually doubling its funding in the budget just a few weeks ago and recognize the importance of basic scientific research for our country and for our future.

Now, Senator Breaux, who is the Ranking Member, I certainly do look forward to working with you and others on this Subcommittee in the months ahead. I do think that it is important that those in the aerospace area, space generally, technology, or in science should feel that this Subcommittee is their portal to the Senate. It is important that they feel comfortable letting us know their ideas. We do not have all the wisdom, all the knowledge, all the insight. You are always welcome to contact me or any of the Members of this Subcommittee if there is a matter that you think is of pressing concern that needs to be addressed by your Government.

The hearing today is focused on aeronautical research at NASA. We hope to discuss the current status, and we also hope to discuss the future of aeronautics. We hope to discuss the process or the glide path that will take us there, and with that in mind, we hope to begin to answer the following questions: What will this glide path be, and is it going to be a glide path up or is it going to be a glide-path down? We want it to be ascending. We also want to know, with the ascension, what will be the potential impact of this investment on commerce, on our economy and jobs, and on national security with a particular focus on maintaining our air superiority?

Over the past few years, there has been a great deal of attention that has been placed upon the space activities at NASA, but today we hope to review the aeronautical aspects or, as some call it, the first "A" of NASA. We have heard about Europe's plan to dominate the aeronautical skies in the future. At the same time, we have heard about a lack of attention given to the U.S. program for the advancements in this area. So the question is, does the United States intend to respond to this competitive challenge from the Europeans, and if so, when and how?

I recognize that the aviation-related manufacturing sector is a net exporter representing many good-paying jobs for our fellow Americans. A loss of these jobs has a direct impact on the quality of life for our constituents.

A study by the National Research Council states that continued reductions in the funding for the aeronautics research and development may have irreversible consequences, and also, once and if U.S. competitive leadership is lost, it is going to be extremely difficult to regain such leadership when one considers the logistical difficulties of reassembling quality infrastructure, the skilled people, and the investment capital that would be needed to restart a lost capable team of professionals and facilities.

We have before us, obviously, key people in organizations that must participate in this research and development that will help U.S. industries respond to this challenge. Obviously, it is good to see Dr. Creedon, and it is great to see the director, Dan Goldin, the key leaders at NASA, and we look forward to hearing from you shortly.

I would say to my fellow colleagues, in addition to this international challenge, we have a national problem as well. We have already heard of and experienced many of the problems at our airports from delayed flights or increasing ticket prices. We look to the near future, and what do we see? No relief in sight. All we see is more gridlock. The Nation, our Nation, cannot and should not accept this inefficient situation. It is clear to me that the future of U.S. aviation relative to both international and national concerns depends on adopting and developing new technologies. The need is both short term and long term, and we must pursue both evolutionary and revolutionary advances.

The aircraft of the future, as expressed by some of the visionaries here, will be cleaner, it will be safer, it will be faster, and it will be quieter. Nanotechnology composites will be a part of achieving this goal. The innovation process that we currently utilize for aeronautics must be reviewed to ensure that it is operating properly and efficiently.

Industry and Government, I think will probably have to establish never-before-seen types of relationships that will move this country in ways that no one has ever dreamt. We must also recognize that the most essential raw material for any innovation or technology development process is human capital, which means knowledgeable, capable, and skilled people, and I am alarmed to hear that the number of U.S. graduates at the bachelor- and master-degree levels in aerospace engineering and related disciplines have dropped by almost 57 percent and 39 percent respectively since 1990. That is not the glide path we want as far as capable people involved in aerospace.

This situation is further complicated by the fact that many of the people who are involved in aeronautics and aerospace are in their mid forties and obviously getting older, but the point is that the skilled aeronautics work force is aging and retiring and new workers are not choosing this field.

Obviously, taxpayer funding or taxpayer investment is always an issue. The fiscal 2002 budget request includes a 7 percent increase for the aerospace technology program at NASA. The majority of this increase is apparently to go toward the second-generation reusable launch vehicle, and I am sure NASA will explore a variety of ways of achieving that and making sure there is no waste of taxpayers' dollars and find the best uses of existing efforts. But I do want to applaud to this end, NASA Director Goldin, for his commitment to aggressively seek new applications for the promising so-called orphan launch vehicle technologies. These efforts ensure that the taxpayers receive maximum benefit from their investment in NASA and, most importantly, that promising experimental technologies continue to be fully utilized throughout the public and private sector.

With regard to funding for aeronautics research and development, some have used the term "crisis"—that is one of the reasons I wanted to have this hearing—in describing this current situation. I am going to personally withhold use of the term "crisis" until we are all much more fully informed, and I hope that our witnesses today will provide the Members of this Subcommittee and, indeed, the entire Senate, with the required evidence in their testimony that will serve as the foundation for future actions on this very, very important issue.

So, with that, I would like to turn it over to our Ranking Member on the Subcommittee, Senator Breaux, for comments.

STATEMENT OF HON. JOHN B. BREAUX, U.S. SENATOR FROM LOUISIANA

Senator BREAUX. Thank you very much, Mr. Chairman, and welcome to the Subcommittee.

Senator ALLEN. Thank you.

Senator BREAUX. We, on our side, look forward to working with you, and I am pleased to hear your comments about the ability for us to influence some of the hearings and receive suggestions as to areas we think we might need to take the Subcommittee.

I want to thank you for calling the hearing today. I appreciate the distinguished witnesses that we have, particularly Dan Goldin, our NASA Administrator, and also I would point out Mr. Dennis Deel, who is president of Lockheed Martin Michoud Operations down in New Orleans. I am delighted to have him here as well.

It is clear that NASA is a leading innovator in the area of aeronautics research. The research is essential to solve the growing air travel crisis of congestion, delay, noise, and pollution that more and more of our constituents face every day and complain to us about the problems. Advanced aeronautic technologies developed at NASA help nearly 600-million Americans fly safely each year. With the number of traveling Americans expected to even triple to .8 billion per year by the year 2020 and a net 3 percent of the gross domestic product stemming from airlines and airline manufacturing, solutions to these problems obviously are crucial to maintaining a healthy U.S. economy.

As you have mentioned, Mr. Chairman, earlier this year, the European Commission announced Europe's commitment to aviation research and development. Their goal is quite simple, to become the global leader in aeronautics by the year 2002. Their own commission report details Europe's vision, and I quote, it says,

> "In 2020, European aeronautics is the world's No. 1. Its companies are celebrated brands renown for the quality of products that are winning more than 50-percent share of the world market for aircraft, engines, and equipment."

That is their goal.

In short, Europe has committed to spend $95 billion on aeronautic research and development over the next 20 years to take over a market that this country has heretofore dominated.

At the same time, NASA's distinguished reputation for being a catalyst for aeronautics discovery may soon fade. According to one of our witnesses, the NASA Aeronautics Support Team, funding for NASA aeronautics research decreased $200 million between 1994 and the year 2001. Also, a study last year by the National Research Council noted that continued reductions in funding for aeronautics and development may have irreversible consequences. Our Nation could lose the infrastructure and the people that we need to fuel the aerospace industry.

Of course, the aeronautics budget is inextricably linked with other aerospace technologies, like the advanced space transportation research and development. To that end, I am disappointed that NASA has terminated its investment in the X-33 reusable launch vehicle program. If successful, the X-33 Venture Star Project would have developed the Shuttle successor, which would have been a more economical large vehicle opening space flight to more and more people. It is my hope that promising tank technologies like those being investigated and researched at Michoud will be worthy of further investment through the Space Launch Initiative.

In conclusion, since the mid–1980s, the U.S. aerospace market share has fallen by more than 70 percent, to nearly half. In order to stay competitive, the United States must answer Europe's challenge and their commitment to aeronautics research and development.

Again, Mr. Chairman, we welcome you, look forward to working with you, and are happy to be cooperative on issues that we can be.

Thank you.

Senator ALLEN. Thank you, Senator Breaux.

Senator Rockefeller, would you care to make any comments?

STATEMENT OF HON. JOHN D. ROCKEFELLER IV, U.S. SENATOR FROM WEST VIRGINIA

Senator ROCKEFELLER. I will just make a very brief comment because Senator Breaux said, as he so often does, much of what I really wanted to say. I want to particularly join him in welcoming you, Mr. Chairman. I am very happy for your presence. I thought your opening statement was important because it showed an enormous sort of sweep and ambition for the Subcommittee. I think that is terribly important, and I think where you come from, the work that you did as Governor, et cetera, all of that bodes very, very well for the Subcommittee. So, I particularly want to personally welcome you and say that we are glad that you are here. We will look forward to working with you, which is the last nice thing I will say, not about you, Mr. Chairman, but in this particular little opening.

I agree with John Breaux when he talks about the reports, the so-called RG 21 reports that are coming out. They bode very badly for aeronautics and the aerospace industry in Europe and how they have reduced us by 50 percent, how they are using WTO illegal subsidies. This is a parallel pattern to Airbus and its European suppliers, their hushkit regulation-type approach to keeping the competition out, even though the hushkit is utterly irrelevant at this point since we meet all of the criteria. They just do not choose to admit that.

Then there is this very interesting and, I think, rather scary habit of the Europeans, and that is of finding a way to block all mergers that could be useful in aerospace involving the United States while simply waving theirs on through.

We think in terms of a $100-billion trade deficit with China and a $60-billion trade deficit with Japan, and both will be higher by the end of this meeting, but what the Europeans do, particularly with respect to aviation and aerospace, a lot that involves NASA is very, very bad and wrong.

I also agree with John Breaux, that if we are going to fight back, we have got to do that with the resources, and the budget authority for NASA's aeronautics research and development program which peaked in 1994. That was 7 years ago, and that is a very long time. It is at $1.36 billion for the fiscal year 2002 budget. I am very, very concerned that, rather than quipping the U.S. aerospace industry to meet new challenges, President Bush's budget proposal calls for the termination of some of these programs, including the rotorcraft, the advanced aircraft, the intelligence synthesis environmental programs.

We have got a lot to do, and all of this within the context of how large our budget is going to be. That makes this a particularly important and interesting Subcommittee, Mr. Chairman, and we will work to resolve problems.

Thank you.

Senator ALLEN. Thank you, Senator Rockefeller.

Now, I would like to recognize another Member of our Committee who is also Chairman of the Aviation Subcommittee, Kay Bailey Hutchison.

Senator Hutchison.

STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Senator HUTCHISON. Thank you, Mr. Chairman, and I am very pleased that you are holding this hearing because this is a very important issue to our country. I am glad that you are focusing on the research capabilities of NASA.

I just want to say that I think that aerospace research and the aeronautics research function of NASA is extremely important, and I think the work that we have done toward an aerospace plane could revolutionize the aviation industry and give us the next significant advantage over our overseas competitors.

I am troubled by the statistics which accompany recent reports on the state of U.S. aeronautics research. Twenty-five years ago, the United States had over 90 percent of the world market for commercial aircraft sales. Ten years ago, it was 70 percent, and today, it is 50 percent. I support efforts to make sure that aviation trade is fair, and we must do everything we can to keep our research advantage in this area.

Our aeronautics research has always included the aviation industry, our military, and NASA. Those players had been working together synergistically for years, and we must continue to do that and make it a priority.

So I am very much looking forward to working with you, Mr. Chairman, and with Dan Goldin who is doing a terrific job at NASA to making the budget numbers fit. We can set priorities and determine what our science research is best suited to do. We must keep our focus, and keep looking toward the next envelope that we can push.

Thank you very much.

Senator ALLEN. Thank you, Senator Hutchison.

We have several panels here. The first panel is Congressman Virgil Goode from the Fifth District of Virginia, and Senator Warner. Congressman Goode, if you would like to come forward. I do not know where Senator Warner is. He was here a moment ago, but we will hear from you first.

STATEMENT OF HON. VIRGIL H. GOODE, JR., A REPRESENTATIVE IN CONGRESS FROM VIRGINIA

Mr. GOODE. Thank you, Mr. Chairman.

Senator ALLEN. Thank you.

Mr. GOODE. Mr. Chairman, Members of the Subcommittee, thank you for allowing me the opportunity to speak on a subject that is of great concern to me and to many Americans.

The name "NASA" is a household word. Yet, many overlook the first "A" in NASA. That "A" stands for aeronautics. The history of NASA is rooted in aeronautics and aeronautics research.

There was a time when NASA was the world's leader in aeronautics research. Increasingly, though, over the past quarter century, NASA has focused more on its space initiative, and other nations have climbed into the lead in aeronautics research. Do not misunderstand me. I support NASA and its work in exploring the frontiers of space, but our military and our civilian travel on Planet Earth deserve fair consideration in funding in NASA's budget for aeronautics research.

For instance, in the last several years, NASA's basic aeronautics research funding has declined steadily. Today, it is about 40 percent of what it was 4 years ago. The civil and military advantages brought about by 80 years of research and the dynamics of flight are now being scaled back at a time when we need to focus on aeronautics more than ever.

The aeronautics segment of NASA's budget has long been a fraction of NASA's total budget. It has dropped by several hundred million in the past few years. Aeronautics research is critical to maintaining market lead and air superiority. The toll on our economy and on our national security of NASA's low priority on aeronautics research has already alarmed many of us.

The crisis in our air transportation system—congestion, delays, cost, incursion, noise, and emission—is well known to most Americans. Without dedicated research and commitment, this is a situation which will only worsen with time.

I am deeply concerned about the decline in the U.S. world aircraft market share. It was once 90 percent. Today, it approaches half of that. Likewise, I have a deep concern about our ability to sweep the skies with our military aircraft. Both of these concerns, which are shared by many, are affected directly by the extent of NASA's advanced research and technology programs.

Let me reiterate, I do not oppose space exploration. However, I believe that the following questions should be asked about NASA's priorities and the consequences for our Nation and for the lives of many Americans in case little or no additional money is added to the request in the President's budget of $14.5 billion for NASA. Those questions are: With millions of Americans affected directly by accelerating problems associated with air travel, why has NASA reduced funding for basic aeronautical research by between 40 to 50 percent? Two, how will the huge cost overrun of the space program affect NASA's allocation of funds for aeronautics research? Three, should NASA be providing hundreds of millions of dollars in collaboration with Russia to train cosmonauts and to provide a safe, comfortable tourist destination for a few Americans when millions of average citizens are dealing with the costly, overwhelmed, hub-and-spoke air transportation system which is in serious need of NASA's research help? Does not NASA need to give more support to small aircraft transportation system research, which would have an enormous benefit to rural districts such as mine, all across America, thereby bringing access and economic development opportunities to rural America? Should NASA's budget allocation for advanced research and support of military applications be curtailed after many years of commitment and collaboration?

In closing, Mr. Chairman and Members of the Subcommittee, thank you for your time, and I hope that NASA in the future can provide adequate aeronautical research that can help to make life in our own country safer and effective in terms of everyday air travel and business opportunities.

Thank you.

Senator ALLEN. Thank you, Congressman Goode.

You posed some very good, tough questions, which I am sure the Subcommittee will want to address, and I hope you will address them on the House side as well.

I know that you were down in Danville last week or fairly recently, the last 10 days, with some advancements as far as the airport there in Danville. I congratulate you and commend you for your important leadership for Southside, Virginia, but also with the advancements of aerospace and technology to improve job opportunities for folks in Southside, Virginia. So thank you for taking time to share your insight with us.

Mr. GOODE. Thank you, Mr. Chairman, and thank you for your help in Southside.

Senator ALLEN. Thank you.

Senator Warner had to start the Foreign Relations Committee meeting, and he will return. So I suggest that we just proceed with Panel I, which is a number-one panel, led by the Honorable Daniel S. Goldin, the Administrator of NASA, and Dr. Jerry Creedon, Director of Langley Research Center of NASA.

If both gentlemen would please come forward.

I would like to first proceed, of course, with our esteemed and beloved Administrator of NASA who has a very difficult task, but nevertheless has showed great wisdom and creativity in keeping NASA afloat and hopefully going to new heights. So we would first like to hear from you, Mr. Administrator.

STATEMENT OF HON. DANIEL S. GOLDIN, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. GOLDIN. Mr. Chairman and Members of the Subcommittee, in late May or early June of this year, the flight of the X-43 will be, for the first time, a non-rocket engine that has powered a vehicle to hypersonic speeds. The concept of a scram jet has been around for decades. Yet, it has been technically infeasible until now.

NASA is turning visionary possibilities into incredible realities. Unfortunately, this potential may go unrealized. U.S. aerospace is in trouble. Domestic investment in both technologies is low. Technology pull from the military has faded. Commercial markets are constrained and beginning to stagnate. Aviation, which was once value-priced, is now becoming a commodity.

Foreign competition and capability are surging. The U.S. aviation system is reaching full capacity and delays are increasing. Evolutionary technology is not the solution. Companies that do not change will not survive. When the markets are constrained, opportunities arrive for revolutionary technologies to break through market barriers and create a new playing field. This is the history of innovation.

It happened when semiconductors replaced vacuum tubes. It happened when airlines replaced railroads, and it will happen in aerospace. The question is: Will it be the United States or another Nation that succeeds?

NASA's job is not to help industry compete at the margines of a constrained market. NASA's job is to enable a future that continues to meet the economic and security needs of our Nation.

Here is our strategy. First, we will focus on aerospace technologies. We should not maintain separate technology efforts for both aeronautics and space.

Second, we are focussing on the public good such as mobility, aviation safety, and noise reductions, not the maintenance of yesterday's industrial base.

Third, we are focussing on revolutionary leapfrog technologies. Information technology, nanotechnology, and biologically inspired technology will be integrated into the traditional aerospace sciences to open up new pathways for innovation and American leadership worldwide.

Fourth, we will develop a new era of engineering tools. An intuitive high confidence, highly networked engineering design environment will allow us to design from atoms to aerospace vehicles with higher quality and much shorter time spans.

Fifth, we must inspire and train the next generation of scientists and engineers to unleash the incredible range of innovation and opportunity that is possible in future aerospace systems.

Mr. Chairman, I might tell you, we have twice as many people over 60 as under 30 at NASA. It is chilling.

So let me reiterate, we are not interested in yesterday. We are here to create tomorrow.

Let us take a quick look at our vision. NASA and the FAA have a longstanding partnership to develop and transition advanced air traffic management technologies. As part of this partnership, NASA is developing 16 cutting-edge sensor and decision support technologies to increase capacity and overcome weather-related delays. If fully implemented, we believe we could increase capacity by 30 percent and reduce delays by 50 percent in the next 7 to 8 years.

We will continue to pursue this approach in the near term. However, within the next decade, even this increased capacity will be outstripped by rising demand. The long-term solution is the transition to a new revolutionary system. America has had the existing system for half-a-century.

Today, about 80 percent of passenger traffic is handled by a little more than 1 percent of the Nation's airports.

Plus, aerospace is under-utilized. We must increase the capacity of our Nation's airports, fully link all our airports to a more distributed system, and decrease the impact of bad weather. As a first step, NASA will pioneer high-fidelity modeling and simulation of the airspace system. It will provide in-depth understanding of how to implement new technologies and will support trace studies for new space system architectures and be a tool for this Subcommittee to help make decisions on future funding.

NASA will ultimately provide the basis for an R&D and transition strategy. NASA will maintain its commitment to our investment for the public good in the near term. Our programs in aviation safety, quiet aircraft technology, and ultra-efficient engine technology will provide key technology advancements, but we will transform our basic research efforts to pioneer a new era in aerospace. Future airframes and engines will rely on emerging technologies that build a system from the molecular or nanoscale, known as nanotechnology. Revolutionary carbon molecules have the promise to be 100 times stronger than steel and only one-sixth the weight. Our future materials will be intelligent with embedded sensors and actuators. Sensors like the nerves of a bird will measure the pressure over the entire surface of the wing and direct the response of the actuators, the muscles. The materials will be extremely flexible, allowing the wing to reform to optimal shapes, remain extremely resistant to damage, and potentially self-heal. The vehicles monitor their own performance, their environment, and their human operators for improved safety.

The vision I have described is possible, and we at NASA are focusing our technology program on it and Mr. Creedon will present some more details of where we are going with the leadership at Langley.

If we are successful, we will transition into an integrated air and space transportation system. The fleet of vehicles will be seamlessly spanned from personal aircraft to launch vehicles, and we will be back to value-pricing instead of commodity-pricing.

I have a 74-second video which I think will describe exactly what we are doing. You may recognize the narrator.

[Videotape presentation.]

Mr. GOLDIN. Mr. Chairman, we are now working with the Department of Defense and Department of Transportation. We intend to have a blueprint available by September to help in the process for the 2003 and 2004 budget process. We will factor what we learn from this hearing into that planning, and we thank you for holding this historic hearing. It has been almost a decade since we have addressed the subject of aeronautics in this panel.

[The prepared statement of Hon. Daniel S. Goldin follows:]

PREPARED STATEMENT OF HON. DANIEL S. GOLDIN, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Subcommittee:

In late May or early June of this year, a B-52 that was designed in the early 1950s will take-off from Edwards Air Force Base in Southern California and head to a test range over the Pacific Ocean. Mounted underneath the starboard wing will be a Pegasus rocket that was designed in the 1980s. Fitted onto the Pegasus in place of the nosecone will be the X-43, a small experimental scramjet (supersonic combustible ramjet)-powered vehicle designed at the Langley Research Center in the mid-1990s. Over the test range, the B-52 will drop the Pegasus, which will fire its rocket engine and accelerate to Mach 7. At that point, if all goes well, explosive bolts will fire and a ram will push the X-43 into free flight. Shortly thereafter, its scramjet will ignite and we will receive combustion data for ten seconds. When its fuel is spent, the X-43 will continue on its flight path before plunging into the Pacific Ocean.

Flight of the X-43 vehicles will be the culmination of over 20 years of scramjet research and the first time a non-rocket engine has powered a vehicle at hypersonic speeds. And while the concept of a scramjet engine has been around for decades—nearly as long as the B-52 that is carrying it to the test range—it has not been technically feasible until now. The talent and vision of the people at our NASA Research Centers are making it feasible, turning visionary possibilities into incredible realities. NASA's job is to envision the future and make it a reality. This is our history and it is our future.

I am confident, even excited about the future we can create. It is incredible and I will describe it to you. Dr. Creedon and I will explain how these exciting possibilities can be made reality through revolutionary technologies we are working on today. But let me be very clear, the aerospace industry is facing serious challenges, our air and space transportation systems are constrained and not meeting the needs of our society, and NASA must transform itself to lead the transition to this new future by managing within the resources provided to us by the American people.

THE IMPORTANCE OF AEROSPACE

First, let me discuss why aerospace is so important. Aerospace is critical to National security, transportation mobility and freedom, and quality of life. Air superiority and the ability to globally deploy our forces are vital to the National interest. The role of air power in winning the Gulf War is a clear reminder of the importance of aircraft in major conflicts. Aviation is a unique, indispensable part of our Nation's transportation system, providing unequaled speed and distance, mobility and freedom of movement for our Nation. Air carriers enplane over 600 million passengers and fly over 600 billion passenger miles, accounting for 25 percent of all individual trips over 500 miles, 50 percent over 1000 miles and 75 percent over 2000 miles. Air freight carries 27 percent of the value of the Nation's exports and imports and is growing at over ten percent annually. Global communications, commerce and tourism have driven international growth in aviation to five to six percent annually, well beyond annual Gross Domestic Product (GDP) growth.

Aviation employs 800,000 Americans in high quality jobs, second only to trucking in the transportation sector. Driven by technology, annual growth in aviation labor productivity over the past 40 years has averaged 4.6 percent, compared to two percent for U.S. industry as a whole. For example, technological advances over the past 40 years, many of them first pioneered by NASA, have enabled a ten-fold improvement in aviation safety, a doubling of fuel efficiency with reductions in emissions per operation, a 50 percent reduction in cost and an order of magnitude reduction in noise.

Aviation manufacturing is a consistent net exporter, adding tens of billions of dollars annually to the Nation's balance of trade. Aviation produces and uses a broad base of technologies—from computing and simulation to advanced materials—supporting the high technology industrial base of the country. Defense aviation provides fast, flexible force projection for the U.S. Our military aircraft are unparalleled globally because they employ the most advanced technology.

Aviation is central to personal freedom, security of the citizenry and the global movement of people and goods in the new economy. Mobility is a prerequisite for freedom. The ability to move freely and efficiently from place to place is a right highly valued by U.S. citizens. Mobility requires transportation that is inherently safe, available on-demand, and affordable. National security and the economic health of the country are heavily dependent on aerospace systems.

The U.S. is the global leader in aviation. From every aspect—technology, products, services, aviation standards and procedures, and National defense—the U.S. sets the mark.

THE AEROSPACE ENVIRONMENT TODAY

Sustaining our leadership and the National benefits we derive from it is far from assured. Both military aerospace research and development (R&D) and procurement have declined, reducing the "technology pull" from the military sector. In past decades, the primary motivation for advances in aerospace technologies was dominated by military needs. The partnership among NASA, Department of Defense (DoD) and industry rapidly advanced, matured and integrated aerospace technologies. These technologies were then appropriated for commercial use, with great success. Examples of this process abound. The turbine engine introduced on the B-707 was originally designed for military aircraft. The Pratt & Whitney J-57 and the General Electric J-79 engines were also originally developed for military use before leading to commercial derivatives. Beyond this, Boeing's Model 367-80, the "Dash 80," was the prototype for both the KC-135 military tanker and the Boeing 707. In the mid-1960s, the U.S. Air Force initiated work that led to the C-5A military transport. Shortly thereafter, the companies in competition to develop the transport all introduced wide body civil transports—the Boeing 747, McDonnell Douglas DC-10 and the Lockheed L-1011. In an additional significant development, revolutionary fly-by-wire flight controls were developed and first adopted for U.S. military aircraft and the Space Shuttle, and Boeing is now incorporating fly-by-wire into its newest commercial aircraft.

Although the increasingly competitive marketplace demands an accelerating pace of technological innovation, the opportunity for commercial industry to draw on defense-related R&D is decreasing. The military aerospace sector is a much smaller share of the overall aerospace market. Furthermore, recent military spending has been focused more on sustaining the current fleet and less on research and technology. According to the Aerospace Industries Association, in 1971, the military accounted for 55 percent of the overall market and by 1998 it was down to 31 percent. For turbojet engines, the decline is even more dramatic. For example, General Electric Aircraft Engines shifted from 70 percent of their business being military to about 20 percent. And for Pratt & Whitney the situation is very similar.

Furthermore, during the 1950s, there were 45 aircraft development programs—during the 1990s, there were only six. Far fewer developments with protracted design and acquisition schedules—an 80 percent increase in the development time for major DoD systems from 5.2 years during 1965-69 to 9.3 years during 1990-94—are the result of increasing system complexity and inefficiencies in design, development and manufacturing. With fewer aircraft developments, there are fewer opportunities for the Nation's declining engineering workforce and experience base to develop design and production skills, crucial in light of the increasing system complexity. A sharp decline in the enrollment in our universities' aerospace engineering departments has paralleled this decline in aircraft development programs. The National Science Foundation reported that between 1992 and 1997 enrollment dropped by 25 percent, and while there has been a slight upturn since, this decline further exacerbated the loss of engineering talent.

The market shift from the military to the commercial sector as the major buyer of aerospace products dictates a corresponding shift in R&D strategy. Industry consolidation—from 25 aerospace corporations two decades ago to four today—has contributed to the substantial reduction in the infrastructure that supports aerospace research and technology. R&D in the aerospace industry is typically in the range of three to five percent of sales. Much is focused on evolutionary product development. This contrasts with other industries. For example, in 1999, the pharmaceutical industry invested 10.5 percent of its sales in R&D and the computer industry invested 26.3 percent of sales. Therefore, at NASA, we shifted our technology development toward revolutionary long-term, high-risk civil needs, while maintaining strong partnerships with DoD and industry to ensure the sharing and application of technologies across military and commercial requirements.

Commercial markets are projected to be extremely large over the next decade. These projections are based on the assumption that the current aviation system can support unconstrained growth. But, just as the Nation (and the world) becomes more dependent on moving people and goods faster and more efficiently via air, important obstacles have emerged. The air traffic and airport systems in both the U.S. and overseas are reaching full capacity. Delays are increasing. Experts agree that the congestion and delay problems experienced throughout the U.S. last summer will only get worse unless drastic action is taken. Each year, airlines must add more "padding" to their schedules to maintain on-time performance and the integrity of their scheduling systems, while facing more congestion in the system. At the same time, legitimate concerns over environmental issues (e.g., noise and emissions) are preventing additions to physical capacity. In 1998, airline delays in the U.S. cost industry and passengers $4.5 billion—the equivalent of a 7 percent tax on every dollar collected by all the domestic airlines combined. With demand projected to double over the next decade, NASA estimates, based on a computer model of operations at the Nation's top 64 airports (80 percent of enplanements), that in the absence of change, annual delay costs will grow to $13.8 billion by 2007 and $47.9 billion by 2017. But growth in airport infrastructure that might offset this problem is not likely in the foreseeable future. Several key airports are unable to gain approval for projects to expand infrastructure because they are in non-attainment areas, where National objectives to reduce emissions have not been met. Therefore, we are seeing constraints to growth that could threaten the commercial prospects of our aerospace industry as well as impact the integrity of our transportation system.

Beyond these numbers lies another serious problem. Because of the networked nature of air transportation, as the system gets closer to its capacity limits, it has less flexibility to deal with unexpected but inevitable events. When the system is operating at its limits, an isolated problem within the system, such as a thunderstorm, creates missed connections, severe delays and canceled flights that ripple throughout the system. This loss of flexibility to deal with unexpected events cuts to the heart of the National imperative to have a dependable transportation system.

Today, these problems are even more acute than in the past. Shortfalls in capacity (i.e., airports, air traffic control and vehicle capability) and problems with the environment are not easily addressed in the private sector. The resulting delays, and noise and emissions pollution are not priced in the market place. These problems are termed "externalities" since, unlike other costs, no market participant pays directly for them. As a result, the private sector has inadequate incentives to address the very real problems imposed by aviation on third parties. NASA is making progress in a number of programs, including Aviation Safety and Aviation Systems Capacity that directly address these externalities.

As the long-haul jet transport has in effect become a commodity in the marketplace, commercial operating margins have become razor-thin. And, although the dollar value of the U.S. share of the world aerospace market has been increasing, from $84 billion in the mid-1980s to $114 billion in the late-1990s, the U.S. share of the total market has been markedly declining. From about 70 percent in the mid-1980s, it is about 50 percent today, in part because of the development of new programs overseas. Future market share could decline even further as European competition becomes more aggressive. The Aerospace Industries Association recently announced that the aerospace trade balance is down $14.8 billion, or almost 35 percent from the record high in 1998 of $41 billion. This includes a drop of $6 billion in civil transport exports and a $2 billion increase in the imports of civil transports.

America should not be lulled into the false security that the U.S. will continue to be the leader in aerospace. The Europeans have reached parity in civil transports, and have laid out a potential path to forge ahead of the U.S. The Japanese have shown significant interest in supersonic transports. If we lack the vision, we run the risk of: constraining our ability to meet the demands on our Nation's aviation system, losing the premier position of our civil industry, fighting battles with out-dated technology, and relying on foreign transports for our personal and business travel.

Anyone who doubts this should read the European plan for aeronautics. The following is an excerpt from "European Aeronautics: A Vision for 2020":

> "In 2020, European aeronautics is the world's number one. Its companies are celebrated brands, renowned for the quality of products that are winning more than 50% shares of world markets for aircraft, engines and equipment. They enjoy the considerable benefits flowing from Europe's fully integrated single market, especially the access to efficient capital markets and the ability to recruit from Europe's pool of well educated and trained professionals. For the European aeronautics industry, gradual realization of our ambitious vision must be facilitated by an increase in public funding. European aeronautics has grown and prospered with the support of public funds and this support must continue if we are to achieve our objective of global leadership. Although it is a preliminary estimate, total funding required from all public and private sources over the next 20 years could go beyond 100 billion Euro."

A VISION AND STRATEGY FOR THE FUTURE

Evolutionary technology is not the solution to these problems. The manufacturers and airlines that do not grasp the impact of constrained markets and revolutionary technologies will not survive. This is not meant to be a harsh criticism; it is simply reality. When markets are large and develop constraints, opportunities arise for new companies or companies that can reinvent themselves to utilize new, revolutionary technologies to breakthrough the market barriers and create a new playing field. This is the history of innovation in the United States. It happened when semiconductors replaced vacuum tubes. It happened when airlines replaced railroads. And it will happen in aerospace.

In this environment, NASA's job is not to perpetuate the past and help industry better compete within a constrained market that does not meet National needs. NASA's job is to focus on the National good and enable a future that can continue to meet the needs of our Nation—for transportation, mobility, and security. That means pioneering revolutionary technologies that break through today's market barriers.

But NASA has its own challenges. Like any Government agency, we are responsible to the taxpayer and seek the highest return with the resources we have available. For the past several years, NASA has had to live within a relatively flat budget. This has required hard decisions about research priorities. Since the mid-1990s, the hard decisions we made resulted in the cancellation of the High Speed Research Program, the Advanced Subsonics Technology Program, and, most recently, the Rotorcraft Program.

In the case of High Speed Research, the program was cancelled on its merits. Our largest industrial partner, The Boeing Corporation, concluded that the program was not going to lead to a market-viable design and essentially canceled its investment. The facts are that the program was not addressing one of the most critical issues—supersonic flight over land. Without the technology to reduce the overpressure of the sonic boom, the vehicle would be limited to over water operation, restricting the market and limiting the viability of the aircraft.

Additionally, jet noise reduction for take-off and landing operations was not going to meet the likely Stage 4 noise limits. While the vehicle would beat current Stage 3 limits by a reasonable margin, the vehicle would have to meet the ever more stringent noise rules. Moreover, to achieve the Stage 3 noise levels required large "box car" nozzles to diffuse the jet noise. These nozzles added weight and cost, further limiting the viability of the vehicle.

So, while we were rightfully proud of the progress the program was making, we had to agree with Boeings conclusions. We made the hard decision to cancel the program.

In the case of the Advanced Subsonics Technology Program, we took the program apart, cancelled the nearer-term elements and transitioned the longer-term, public good elements to other programs. In this way, we maintained our efforts in noise reduction, emissions reduction and aviation system capacity improvements.

Most recently we canceled the Rotorcraft Program. It was cancelled because it was too near-term and not sufficiently focused on the advanced concepts that might allow vertical flight to play a critical role in our future air transportation system.

I do not want anyone to conclude from this that these vehicle-classes are not important or that NASA is not pursuing some research in these areas. For example, in the area of supersonics, we have developed a new partnership with DARPA to aggressively address the most significant challenges to sustained supersonic flight over land. Rather than a big, point-design program that characterized the High Speed Research Program, this is a pre-competitive study to address the core issues—efficiency, engine jet noise, sonic boom overpressure, and emissions. The approach is to consider revolutionary technologies that address the fundamental physics of these issues. Once we have a sufficiently explored a broad range of promising technologies, we'll work to develop and fund a more substantial industrial partnership.

There are those that for the health of the industry want us to fund a multi-billion dollar initiative now. This may provide short-term gain to the industry, but that is not NASA's role. And I will not agree to that approach.

Let me be crystal clear—we aren't going to look out the back window of the bus dreaming fond memories of the way things were. Fond memories do not get us to the future. Instead, we will be driving the bus—looking forward, making tough decisions and determining our future.

So, let me describe our strategy for moving forward. First, we will focus on aerospace. We must solve the most critical problems across the board in aerospace—but do it once. We are not going to maintain separate technology efforts, in structures and materials for example, for both aeronautics and space.

Second, we are focusing on the public good—not the maintenance of yesterday's industrial base. When we do this we create new opportunities. For example, NASA is focusing on the mobility of the U.S. people in our Small Aircraft Transportation System (SATS) program. Let me describe SATS. Over 90 percent of the U.S. population lives within 30 miles of an airport. However, most of the airports are small, non-towered and without radar surveillance. We also do not have a very small, smart, safe and efficient fleet of aircraft to use this network of airports. In other words, most of the U.S. airport infrastructure falls outside the modern air transportation system. But this does not have to be the case. Utilizing GPS, a relatively inexpensive suite of electronics and sophisticated software we can turn these "dumb" airports into "smart" airports that would allow them to actually leapfrog into a new era of intelligent, flexible airport facilities. It is also possible to enable a new generation of aircraft that can support this network of intelligent small airports. The first steps down this path are being made by new companies like Eclipse Aviation using NASA technologies to produce inexpensive, safe small jets that will provide air taxi service point-to-point to small airports. The SATS program is focused on enabling this future. So, in focusing and innovating on mobility NASA is creating new opportunities for U.S. industry and we are already seeing new companies being formed. The future is unfolding before us if we choose to look.

Third, we are focusing on revolutionary "leap-frog" technologies—this means integrating radical new technologies such as information technology, nano-technology and biologically-inspired technologies into the traditional aerospace sciences to open up new pathways for innovation. For example, we can now envision a wing that "morphs" its shape, a structure that heals itself, and a control system that senses and controls its own operation down to the molecular level.

Fourth, we will develop a new era of engineering tools and processes. Assured safety, high mission confidence, fast development times, and efficiency in developing revolutionary aerospace systems must become the benchmarks of our future engineering culture. To meet these needs, NASA will develop the tools and system architecture to provide an intuitive, high-confidence, highly-networked engineering design environment. This interactive network will unleash the creative power of teams. Engineers and technologists, in collaboration with all mission or product team members, will redefine the way new vehicles or systems are developed. Designing from atoms into aerospace vehicles, engineering teams will have the ability to accurately understand all key aspects of its systems, its operating environment, and its mission before committing to a single piece of hardware or software. We will drive the design cycle time back down from the 9-plus years it takes today to 3 to 4 years while increasing the quality of design.

Fifth, we must train the next generation of scientists and engineers. If we are to truly develop an entirely new approach to aerospace engineering and our aerospace transportation systems, we must motivate our students by focusing on the incredible range of innovation and opportunity that is possible and educate them so they can make it reality.

So, let me reiterate—we're not interested in yesterday, we are here to create tomorrow. This is not your father's or your mother's NASA. So, even with a tight budget, we are reinvesting for the future. We have a vision for a 21st Century Aerospace Vehicle to focus our investments on the new functionality and performance enabled by the revolutionary technologies I described. We have augmented our Aviation Capacity Program to focus on new aviation system architectures and the sophisticated modeling and simulation required to support it. And we have consolidated efforts to create a new Computing, Information and Communication Technology Program to focus on more revolutionary information and nano-technologies and their application to aerospace systems.

So, let me now describe what is possible when you focus on the issues of mobility and transportation and apply this new technology paradigm.

Improving and Ultimately Revolutionizing Air Traffic Management—While the addition of new airport infrastructure will be limited and costly, the existing system can be improved by leveraging technology advances in digital communications, precision navigation, and computers. Currently the FAA is replacing aging computer, display and navigation equipment in an effort to modernize the infrastructure upon which the ATC architecture operates. Within that architecture, air traffic controllers need improved computer aids to help them plan and manage air traffic more efficiently. As an example, through the FAA Free Flight Program, the FAA implemented the NASA developed Center-TRACON Automation System (CTAS) at the world's busiest airport, Dallas-Fort Worth, to support daily operations in all weather conditions, 24 hours a day, 7 days a week. CTAS provides computer intelligence and graphical user interfaces to assist air traffic controllers in the efficient management and control of air traffic. The system has allowed a 10 percent increase in landing rate during critical traffic rushes. These improvements have translated into an estimated annual savings of $9M in operations cost.

In fact, NASA and the FAA have a long-standing partnership on air traffic management systems. NASA uses its unique technical expertise and facilities to develop advanced air traffic decision support tools, improve training efficiency and cockpit safety through human factors research, and develop advanced communications, navigation and surveillance systems. The FAA defines system requirements and applies its operational expertise to ensure that the technically advanced airborne and ground equipment, software and procedures developed by NASA are operationally useful, efficient, safe and cost effective. The FAA performs complementary research in the application of new technologies in addressing airborne and ground-based communications, navigation, and surveillance needs and in new decision support tools for strategic management of the system.

Overall, NASA is currently working on a suite of 16 technologies, of which CTAS is a subset, to improve gate-to-gate air traffic management to increase capacity and flexibility and to overcome airport capacity constraints due to weather. Most of these are Decision Support Tools that increase the efficiency of operations within the current infrastructure. And while these tools will add critical capacity and improved flexibility over the next several years, the capacity increases they provide will soon be outstripped by increasing demand. They will not fundamentally solve the capacity crisis, reverse the rise in delays or prevent the disruptive, chaotic behavior of the system.

The remaining technologies that NASA is working on add new capability beyond the current system for the worst delay problem: airport delay in adverse weather. These technologies rely on transitioning to satellite-based surveillance and navigation utilizing the National Airspace System (NAS) implementation of DoD's Global Positioning System (GPS). This implementation is under development but has not yet been achieved for full system operation. A critical element of this deployment is implementing a Wide Area Augmentation System (WAAS) to ensure reliable signal availability over the entire U.S. Realistically, however, it will be several more years before the current issues associated with FAA's required WAAS can be solved. Therefore, this suite of tools will not be available until GPS/WAAS is available.

NASA models indicate that these technologies fully implemented across the system would increase operational capacity by about 30 percent and reduce future predicted delays by about 50 percent. However, we should note that full implementation of the entire suite of technologies is not within the scope of the FAA Free Flight Program.

It is absolutely critical to aggressively pursue this approach in the near term. However, we must go beyond the near-term and achieve transition to a new system that is revolutionary in its scope and capacity. The current system structure, where most passengers and cargo are carried by tens of air carriers through tens of airports, must be revised to permit the continued long-term growth of the system. The thousands of airports distributed across this country are a true National asset that can be tapped with the right technology and the right Air Traffic Management (ATM) system. Also, "airspace," one of the nation's most valuable national resources, is significantly underutilized due to the way it is managed and allocated. Therefore, the airspace architecture of the future must increase the capacity of the Nation's major airports, fully tie together all of our Nation's airports into a more distributed system, and create the freedom to fly in a safe, controlled environment throughout all of the airspace.

One thing that will remain constant is that free market forces will drive the air transportation system. Therefore, the future system architecture must be flexible to respond to various transportation system possibilities, not constrain them. The airline industry must have the flexibility to move and expand operations to be responsive to transportation demands. This is the highest level guiding principle for the future ATM system. The next tier of system requirements are robustness (a system that can safely tolerate equipment failures and events such as severe weather) and scalability (the ATM system automatically scales with the traffic volume). One possibility for achieving scalability would be achieved by building the ATM system into the aircraft, so that as you add aircraft to the fleet the ATM system would automatically scale to accommodate them.

The system will be built on global systems, such as GPS, to allow precision approach to every runway in the Nation without reliance on installing expensive ground-based equipment, such as Instrument Landing Systems at every airport. However, the robustness of the global communication, navigation and surveillance (CNS) systems must be such that the system can tolerate multiple failures and still be safe. This is a significant challenge upon which the new architecture depends.

If we are successful at meeting the challenge of a robust global CNS, then with precise knowledge of position and trajectory known for every aircraft, it will no longer be necessary to restrict flying along predetermined "corridors". Optimal flight paths will be determined in advance and adjusted along the way for weather and other aircraft traffic. This fundamental shift will allow entirely new transportation models to occur. For example, with precision approach to every airport in the U.S. and a new generation of smart, efficient small aircraft, the current trend of small jet aircraft serving small communities in a point-to-point mode could be greatly extended.

Airborne self-separation will become the dominant method of operation. Each aircraft will become capable of coordinating and avoiding traffic. They will have full knowledge of all aircraft in their area and will be able to coordinate through direct digital communication with other aircraft. The pilot will be able to look at his flight path at different scales—from a strategic view of the entire origin to destination route showing other aircraft and weather systems, to a tactical view showing the immediate surroundings and flight path over the next few minutes. Aircraft will employ synthetic vision—which uses advanced sensors, digital terrain databases, accurate geo-positioning, and digital processing—to provide a perfectly clear three dimensional picture of terrain, obstacles, runway, and traffic.

By empowering the pilots to control their own flight paths, the system can operate at maximum efficiency and will change the role of the air traffic controller to more of an airspace manager who will manage the traffic flows and system demand. The air traffic "manager" will have a full three dimensional picture of all aspects of the airspace system. The highly compartmentalized "sectorization" of the airspace would be largely eliminated. Through direct interaction with the three dimensional, high-fidelity representation of the system, they will dynamically reconfigure the airspace based on weather systems, equipment failures, runway outages, or other real-time problems. Intelligent systems will provide expert support to such decision making. This real-time airspace redesign will be uplinked to aircraft to recompute flight trajectories. They will also manage the allocation of scarce resources, such as runways when there are conflicts that cannot be resolved between aircraft directly.

Eventually, the entire system will be fully monitored for faults and other risks. The system will move from a paradigm of being "statistically safe" to real-time knowledge of risk and safety. In addition, with pilots and air traffic managers having full data and situational awareness of the system, a new level of collaboration can occur allowing them to work in close partnership to correct anomalous situations.

The future system will truly be "revolutionary" in scope and performance, but it must also be implemented in a mode that allows continuous safe operations to occur, even in the face of unpredicted events. In designing the future airspace system, a systems engineering approach must be used to define requirements, formulate total operational concepts, evaluate these operational concepts, and then launch goal-oriented technology activities to meet requirements and support the operational concept.

This is an extremely complex problem. The system is dynamic and real-time. At the same time, system integrity is absolutely essential. It can not be turned off and it is highly interconnected. At the present time, we believe it will take a substantial public-private partnership to tackle such a large and difficult problem. And yet the payoff from a capacity, efficiency and safety perspective is absolutely enormous.

A Revolution for Aerospace Vehicles.—Revolutionizing the airspace system alone is not enough. An entirely new level of vehicle efficiency, functionality and environmental compatibility must be achieved to meet the challenges of safety, noise, emissions and performance required in this new aviation system. The aircraft of the future will not be built from multiple, mechanically connected parts. The aircraft will have "smart" materials with embedded sensors and actuators. Sensors—like the "nerves" of a bird—will measure the pressure over the entire surface of the wing and direct the response of the actuators—the "muscles." These actuators will smoothly change the shape of the wing for optimal flying conditions. The control surface will be integrated with, instead of an appendage of, the wing, as they are today. Intelligent systems made of these smart sensors, micro processors, and adaptive control systems will enable vehicles to monitor their own performance, their environment, and their human operators in order to avoid crashes, mishaps, and incidents. Distributed as a network throughout the structure they will provide the means for embedding a "nervous system" in the structure and stimulating it to create physical response and even change shape. They will also serve as the means for sensing any damage or impending failure long before it becomes a problem.

These future structures rely on an emerging technology that builds the systems from the molecular, or nano-scale—known as nanotechnology. Revolutionary carbon nanotubes have the promise to be 100 times stronger than steel and only ⅙ the weight. We are at the leading-edge of this technology, transitioning from fundamental physics to building actual macroscopic materials. Much work remains to be accomplished. If we are successful, an aircraft made from this material could weigh as little as half a conventional aircraft manufactured with today's materials and be extremely flexible allowing the wing to re-form to optimal shapes, remain extremely resistant to damage, and potentially "self-heal." The high strength-to-weight ratio of these nano-materials could enable new vehicle designs that can withstand crashes and protect the passengers against injury.

The application of high temperature nano-scale materials to aircraft engines may be equally dramatic. Through successful application of these advanced lightweight materials in combination with intelligent flow control and active cooling, thrust-to-weight ratio increases of up to 50 percent and fuel savings of 25 percent are possible for conventional engines. Further advances in integrating these technologies might result in novel engine concepts that simplify the highly, complex rotating turbomachinery. Other future concepts include alternative combustion approaches and the potential to move toward hybrid engines. Combined with intelligent engine control capability, such approaches may enable integrated internal flow management and combustion control. It also has the potential to integrate both the airframe and engine systems for unprecedented efficiency and directional control capability.

To take full advantage of nano-materials, new computational tools using advances in information technology are required. Tools that take advantage of high-speed computing will enable us to develop large-scale models and simulations for the next generation of vehicles. High-fidelity, collaborative, engineering environments with human interfaces will enable industry to accurately simulate an entire product life cycle, dramatically cutting development costs and schedules. The increasing performance demands and system complexity require new tools to adequately predict the risk and life cycle costs of new aircraft. New computing techniques and capabilities can be exploited to develop robust designs by capturing knowledge and identifying trends to anticipate problems and develop solutions during design rather than after development. These simulations require tools that deal with the increasing complexity of future systems and could offset the diminishing design team experience base in this country. No longer will we design the engine and airframe independently, but rather the computational tools could allow fully integrated vehicle-engine design, integrated health management, and management of the total vehicle air flow both inside the engine and outside the aircraft. These new integrated propulsion and vehicle technology advancements could not only optimize subsonic flight regimes, with twice the thrust-to-weight ratios, but also enable sustained supersonic flight with minimal impact due to sonic booms or other environmental concerns for both civilian and military applications.

In the very long term, comparable advances in electrical energy storage and generation technology, such as fuel cells, could completely change the manner in which we propel aircraft. Future aircraft might be powered entirely electrically. In one concept, thrust may be produced by a fan driven by highly efficient, compact electric motors powered by advanced hydrogen-oxygen fuel cells. However, several significant technological issues must still be resolved to use hydrogen as a fuel, such as efficient generation and storage of hydrogen fuel and an adequate infrastructure necessary for delivering the fuel to vehicles. Success in this effort could end the Nation's dependence on foreign sources of energy for transportation. Revolutionary technologies such as these are prime areas for significant university involvement.

If we are successful, what will the vehicle of the 21st Century look like? It will be radically different from the commercial transport of today whose basic configuration has not changed since the introduction of the Boeing 707 and turbojet engines in the late 1950s. The design flexibility that the revolution in materials and computing technologies provides could enable aircraft whose shape could change to meet a range of performance requirements, for example, range, maneuverability and radar cross-section. With new fuel cell power systems, zero emissions may be possible, and the only noise would be that generated by the air flowing over the vehicle. The wing shape may be changed during flight to control the vehicle, eliminating the need for flaps and conventional control surfaces and their associated drag, weight and complexity. These aircraft could be flown in an air transportation system with unparalleled safety that allows hassle-free, on-demand travel to any location. The beneficial variations are potentially limitless—truly revolutionizing air vehicles, not only commercial and military aircraft, but also personal air vehicles and the utilization of more of the 5400 airports thus providing service to small communities and rural regions that today do not have easy access to air travel.

THE NASA CHALLENGE

So, now I return to where I started. NASA's job is to envision the future and make it a reality—that is, to make the possible feasible. This is our history and our mission. It is about America's future. The vision I described is possible and we at NASA are focusing our technology program on it.

We take this very seriously—we believe it is our responsibility and will do everything within the resources we are allocated to make it happen. I'm not here to claim this is easy or without risk. But the American people expect NASA to take that risk and be pioneers.

We are taking the following actions. **We must partner with the FAA and the Department of Transportation to improve and ultimately revolutionize air traffic management.—**NASA is a key partner with the FAA in the future of the air transportation system. Through the unique talents and history of the Agency, we have become the National leader for research and technology for air traffic management. NASA is prepared to continue this leadership and to be a catalyst for positive change. We will also ensure a smooth hand-off through product development and certification. We will work with the FAA to get the maximum capacity out of the current system. We believe it is absolutely essential that the Nation take a long-term perspective and begin now to enable the high capacity, distributed system we need for the future. Within the next few weeks, FAA Administrator Jane Garvey and I will reaffirm this partnership in a joint letter to Secretary of Transportation Norm Mineta, who is providing bold leadership in addressing the challenge.

We must invest our available resources in the revolutionary technologies that will enable this vision for aerospace vehicles.—The government's role is not to subsidize industry. However, it is unreasonable to expect the private sector to make the necessary high-risk, long-term, decadal, investments to achieve the vision. Government will need to reinvest existing evolutionary aeronautics research and technology resources in the basic research necessary to enable a 21st Century aerospace vehicle. Government aerospace research will focus on public good and leap-frog technologies.

We must strengthen our public-private partnership.—The reinvestment of evolutionary technologies to revolutionary technologies results in significant changes in NASA and will cause disruptions in our current partnerships. Therefore, we must restructure our partnerships to ensure appropriate cooperation and technology transfer. This is imperative if we are solve the problems, remove the constraints to growth and break through current market barriers.

We must form partnerships with academia and the entrepreneurial sector to reverse the decline in expertise.—There is a looming crisis in U.S. expertise—from relatively inexperienced design teams to reductions in research and development to reduced enrollments at universities. Leadership is required to reverse this trend. We, in partnership with the academic community, must begin developing a new generation of scientists and engineers that blend traditional competencies, such as aerodynamics, material and structures, and guidance and controls, with the emerging competencies in nanotechnology, biotechnology and information technology. We must also develop the design tools and environments that will allow us to integrate fewer and more specialized scientists and engineers into effective teams capable of designing highly complex integrated aerospace systems. Very soon, we will establish several university engineering research centers to provide the environment and learning required for this next generation to be ready.

We must identify the National facilities that support this vision and eliminate the rest.—Over the past several years many reviews have been performed relative to our National aeronautical facilities. There have been closures and changes. However, more needs to be done to avoid the perpetuation of marginal facilities through small, evolutionary change. We are optimistic that looking to the future and a revolutionary vision will provide the framework necessary to define the facilities, new and existing, integrated together with computational tools in virtual space will enable a new era in aerospace.

Thank you, Mr. Chairman and Members of the Subcommittee. I commend you for taking on this issue, and appreciate the opportunity to testify today and describe our vision and the actions we are taking for the future of this Nation in aerospace technology.

Senator ALLEN. Thank you, Mr. Administrator. We will have some questions, but we will first hear from Dr. Creedon.

Dr. Creedon.

STATEMENT OF DR. JEREMIAH F. CREEDON, DIRECTOR, LANGLEY RESEARCH CENTER, NASA, HAMPTON, VA

Mr. CREEDON. Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to speak today. The Administrator has provided a very challenging vision for air traffic management and a long-term vision for revolutionary vehicles. Our role at Langley and at the other NASA research centers is to turn these visions into reality. This is our role, and it is our heritage. Our mission is to take on long-term, high-risk, high-payoff challenges that are behind the risk limit or capability of industry, and to deliver validated technologies that meet these challenges.

Today, I will describe three such technologies and make a comment on our budget. The scientists, engineers, and technicians at Langley have never been afraid to tackle problems thought to be too difficult to solve. An excellent example is wind shear, a phenomenon responsible for half of all aviation fatalities from 1975 to 1985.

Wind shear is a spatially, very concentrated downward flow of air which, in effect, pushes aircraft into the ground. What makes wind shear especially hazardous is that there is often no visual clue of its presence. Langley, in cooperation with the FAA, undertook a program to develop a sensor that could look out ahead of the aircraft, detect a harmful wind shear, and enable the airplane crew to safely fly around the hazard. At that time, the general view was that this problem was technically too tough to be solved. It was certainly beyond the risk limit of commercial enterprises.

Nevertheless, in a relatively short time, sensors were developed, and using NASA's Boeing 737 flying laboratory, the sensors successfully demonstrated the ability to detect wind shears and give the crew adequate warning.

There are now 4,000 aircraft worldwide using this technology. This is an example of the payoff of the NASA research centers, a high-risk, high-payoff task, brought into everyday use. The point here is that we can accomplish very difficult technological tasks.

I want to talk about noise reduction. The noise produced by commercial traffic landing in airports must be dramatically reduced if we are to meet the quality-of-life expectations of people living near these airports.

Without going into specific technologies, I will use a map of the area around Chicago's O'Hare Airport to show the impact of the results achieved to date in our noise reduction program.

The large blue area that you can see in this map represents the locations subjected to a level of outdoor noise exposure that exceeds the EPA standard for public health and welfare. Over 600,000 people live in this area.

Our objective is to reduce the objectionable noise to within the airport boundary, an area indicated by the red dots near the center of the diagram. We have already made terrific progress. If every aircraft operating into O'Hare Airport was equipped with the technology we have already developed, the boundary of the objectionable noise would be reduced to the area shown in green, and over 400,000 fewer people would be subjected to this noise level. And that is just in Chicago.

Much of what we do significantly improves the Nation's quality of life. The Administrator has called on us to create technology for revolutionary aerospace vehicles. If we can emulate the characteristics present in nature, then we will be able to develop the ability to achieve revolutionary civil and military aircraft. Rather than optimizing the vehicle shape for just one phase of flight, we could have an aircraft, such as was shown in the video that preceded my testimony, that could effectively and continuously change its shape to obtain optimal performance at all flight conditions.

The visual shown here is an aircraft shape. The grid pattern represents locations where to obtain optimal performance, sensors, and actuators would be located, and the actuators, like the feathers on a bird, could be individually deployed.

In the past several years, we have developed two types of piezoelectric actuators at Langley, actuators that could be used for the purpose of making these deflections. Each of these earn the prestigious IR–100 Award for being an outstanding new technology.

We are now seeing a simulation of an actual flight of a vehicle of this type where the control is obtained just by using actuators like the one I talked about earlier to make little bumps that disturb the airflow at appropriate places on the wing. This film clip shows—and next year, we plan to test this out in that wind tunnel—that we are on the path to achieving the vision the Administrator described. Because we are on that path, revolutionary capability advances in civil and military aircraft are soon to follow.

Let me close with a brief comment on the budget. We accept and support the budget the country has provided. Within that budget, we have tightened our belts. We are operating efficiently, and we have prioritized our efforts to pursue the highest-payoff items. We are accomplishing excellent high-payoff research goals that will benefit the quality of life in the country through enhancements and safety, increases in airspace system capacity, reductions in noise and emissions, and through contributions to the preeminence of military aircraft.

The resulting program represents a viable effort. Hearings such as this serve as a useful tool for increasing the understanding within the Congress and in the Nation of this very important subject.

I am happy to have been able to contribute to the discussion. Thank you, Mr. Chairman.

[The prepared statement of Mr. Creedon follows:]

PREPARED STATEMENT OF DR. JEREMIAH F. CREEDON, DIRECTOR, NASA LANGLEY RESEARCH CENTER

Mr. Chairman and Members of the Subcommittee:

Thank you for the opportunity to speak about NASA's technology development in support of the bold new aeronautics vision outlined by our Administrator, Daniel Goldin.

For the past 50 years we have been flying commercial transport aircraft that fairly closely resemble the Boeing 707, the first commercial jet transport, and we have been operating an air traffic control system based on centralized control concepts developed over 50 years ago. Significant advancements have been made to improve the performance and efficiency of 20th Century aircraft and our national airspace system over these five decades. Despite these enhancements, the public expects better performance and better performance is required to maintain and improve their quality of life. Our citizens want to fly more often, go to more locations, arrive on time, and be assured of improved safety and security. Airport neighbors want reduced noise and emissions. Businesses need affordable, on-time, secure delivery of freight virtually anywhere in the world.

Mr. Goldin has described both a bold new vision for the future of aeronautics in meeting these quality of life needs and a strategy for attaining this vision. He has presented a revolutionary approach to air traffic management and described a new perspective on revolutionary aerospace vehicles. The strategy he has set forth requires the simultaneous development of technologies to help improve the performance and safety of the existing aircraft and airspace traffic management system and technologies that achieve the longer-term visions he described.

The mission of the people at the NASA Research Centers is to turn these visionary possibilities into realities. Today, I want to tell you about some of the exciting new aeronautical technologies being developed at NASA that support the Administrator's vision for what NASA's aeronautics research can contribute to the Nation.

Langley Research Center (LaRC) is one of five NASA field centers providing the primary contributions to achieving the research goals of the Aerospace Technology Enterprise. Ames Research Center is focused on Information Technology, Glenn Research Center is focused on Power and Propulsion, Dryden Flight Research Center is focused on Flight Research, Marshall Space Flight Center is focused on Space Launch Vehicles, and Langley Research Center is focused on Aerospace Vehicle Technologies for atmospheric flight. While the areas listed are their primary focus, all of the Centers are engaged in a broad range of research activities that support the agency goals.

I will concentrate on the research being done at Langley. The examples I will discuss are typical of the excellent work also being done at the other NASA Research Centers.

LANGLEY RESEARCH CENTER CONTRIBUTIONS TO QUALITY OF LIFE

As Director of the Langley Research Center, I am proud that our researchers are engaged in many research tasks that substantively contribute to the Nation's quality of life. They are studying the composition and evolution of Earth's atmosphere as an aid to policymakers, providing technologies for planetary exploration to extend the space frontier, working to reduce the cost of access to space, and helping assure the superiority of our military aircraft. The innovation inherent in Langley's efforts is underlined by the fact that the Center's researchers have been awarded over 200 patents in the last 5 years and have received over 30 of the prestigious "IR 100 Awards" given annually by the Research and Development magazine as one of the one hundred most-significant new technical products of the year. We, at Langley, also ensure that the benefits of our research are shared with non-aerospace firms and have licensed almost sixty technologies in the last few years.

The mission of the Langley research center is to take on long-term, high-risk, high-payoff technical aerospace challenges that are beyond the risk limit or capability of industry and to deliver validated technologies to address these challenges. The Administrator has provided a very challenging vision and our role at Langley and the other research centers is to turn it into reality. The vision he has articulated may seem very difficult to attain; however the scientists, engineers and technicians at Langley have never been afraid to tackle and master problems thought too difficult to solve and we welcome this challenge. An excellent example of this culture is seen in the Center's contributions to eliminating the impact of wind shear on aviation safety.

Wind shear is a spatially very concentrated and often very intense downward flow of air. From 1965 to 1985 this phenomenon was the most significant single factor responsible for aviation fatalities. Langley, in conjunction with the FAA, undertook a program to develop a sensor that could look out ahead of the aircraft and detect a wind shear with enough advance notice to enable the crew to fly around the hazard. At that time, the general view was that this problem was technically too tough to be solved. It was certainly beyond the risk limit of commercial enterprises. Nevertheless, in a relatively short time, sensors were developed, and using NASA's B–737 flying laboratory, the ability to detect wind shears and give the crew adequate warning to safely fly around the hazard was successfully demonstrated. There are now 4,000 aircraft worldwide using this technology. This is an example of the payoff of the research performed at the NASA Research Centers—a high-risk, high-payoff accomplishment brought into everyday use.

Military aircraft also directly benefit from our research. The F-18 E/F production was threatened when the aircraft exhibited "wing rock" (a severe un-commanded roll maneuver of the aircraft) during flight tests. The solution to this problem was a "porous wing fairing" which had been conceived and validated by researchers at Langley. When the F-18 E/F aircraft were retrofitted with this fairing, the "wing rock" was eliminated, thus avoiding a costly redesign or program cancellation.

IMPROVING THE AIR TRANSPORTATION SYSTEM

Anyone who travels by air knows that our national air transportation system is approaching gridlock. Flight delays totaling three million hours were recorded in 1996. Studies indicate that those delays will rise to over 9 million hours by 2007 and to 25 million hours by 2017. In FY 2000, the National Business Travel Association estimated the annual cost of delays at $5 billion with a loss of 1.5 million work-hours. As time increasingly becomes the "scarce commodity" of the information age, the demand for aviation transportation is outpacing the capacity of today's hub-and-spoke system. Thus, when speed is at a premium, the nation's doorstep-to-destination travel speeds are getting worse, not better.

In accordance with the strategy expressed by the Administrator, research efforts at NASA are simultaneously addressing improvements to the existing system as well as trying to provide breakthrough system concepts that will change the air traffic management paradigm. Two technological improvements to the existing system are related to reducing the capacity-limiting aspects of wake vortices, and improving the capacity of airports in conditions of poor visibility.

Wingtip vortices—the turbulent wakes generated by an aircraft—can cause a loss of control by an airplane following too closely behind the aircraft generating the wake. A recent successful demonstration showed NASA's ability to predict both the strength and decay characteristics of aircraft wing tip vortices created during take-offs and landings. When this improved knowledge of wake vortex characteristics has been demonstrated to the level of certainty required for daily use in the air traffic management system, the spacing between aircraft can be safely reduced and capacity increased. Studies have shown that peak airport capacities could be increased between 6 percent and 12 percent depending on the specific mix of aircraft types at a given airport. This level of capacity increase is significant because of the leveraging effect between capacity changes and delays. When a system is operating near saturation, small changes in capacity result in very large changes in delay.

Many of the nation's busiest airports have closely spaced parallel runways. Under clear weather conditions aircraft using these runways can operate independently. As visibility decreases, aircraft cannot be seen well enough to ensure there will be no conflicts as a result of one of the aircraft departing from its appropriate flight path. In this situation, safety requirements demand controllers stagger the positions of aircraft operating on parallel runways. In some cases, operations using one of the runways are eliminated entirely. In either case, capacity is reduced. NASA's B–757 was used to demonstrate the technical feasibility of a system in each aircraft that senses the precise location of neighboring aircraft approaching on the closely spaced runways and issues appropriate warnings or evasive maneuver instructions to the flight crew as warranted by safety considerations. With this Airborne Information for Lateral Spacing technology in place, the reduction in capacity can be safely avoided.

The Ames Research Center has conceived, developed, and deployed many software support tools to aid air traffic controllers in obtaining improved capacity and traffic handling performance. These tools assist controllers in providing efficient runway surface operations and runway use, scheduling and metering aircraft into terminal areas at a rate that equals airport capacity, and sequencing and spacing arriving and departing traffic. They have been deployed and evaluated in the existing air traffic management system and have provided excellent support to the controllers in organizing and efficiently controlling the flow of aircraft. The tools are now being readied for more widespread application.

In addition to these improvements in the capacity of the existing Air Traffic Management System, we are participating in developing a breakthrough approach to provide enhanced mobility by utilizing this country's more than 5000 public use airports.

SMALL AIRCRAFT TRANSPORTATION SYSTEM (SATS)

The past 7 years of investment by NASA in small aircraft technologies coupled with changes in liability legislation have led to the emergence of a new generation of small aircraft. The NASA contributions to this new generation of safe and affordable aircraft were made through the Advanced General Aviation Transport Experiments (AGATE) Alliance and the General Aviation Propulsion (GAP) Program. The technologies developed, coupled with the Generation Aviation Revitalization Act of 1994 and with burgeoning market demand, have supported a dramatic industrial recovery over the past 5 years (1995–2000). The combined impact of these factors has resulted in more than a 300 percent growth in aircraft deliveries, more than a 350 percent growth in industry billings, over 20 percent improvement in fleet safety, recovery to about 20 percent of export deliveries, with about 10 percent annual growth of jobs in this sector.

New aircraft currently going into production have greatly benefited from NASA research. The aircraft include twin turbofan-powered, four- to six-place pressurized aircraft, and several new single-engine aircraft. These new aircraft possess near-all-weather operating capabilities and are compatible with the modernization of the National Airspace System. However, these new aircraft will not make the new transportation innovation fully available to the general public unless new concepts for airspace architecture and operations can be developed.

Fortunately, more than 98 percent of the U.S. population lives within a 30-minute drive of one of the over 5,000 public-use landing facilities. This infrastructure is an untapped national resource for mobility. The concept of a Small Aircraft Transportation System (SATS) offers a safe travel alternative, freeing people and products from transportation delays by creating access to more communities in less time. SATS is based on a new generation of affordable small aircraft operating in a fully distributed system of small airports serving thousands of suburban, rural, and remote communities. The safe, efficient utilization of smaller aircraft and smaller airports can provide a revolution in community accessibility and in public mobility. The system of enabling technologies can be developed and integrated to give the nation near-all-weather access to virtually every runway of these public-use facilities.

Today, small aircraft operating in airspace typical of small community airports are limited to "one-in, one-out" in low-visibility conditions. Air traffic controllers limit only one aircraft at a time in the airport vicinity due to the lack of both radar coverage and reliable communications. The SATS concept integrates high bandwidth wireless communications and Global Positioning System (GPS) technologies to enable multiple aircraft to land and takeoff at community airports. This capability will exist even under reduced visibility weather conditions, and without the need for expensive control towers and ground-based radar systems.

NASA is working with the FAA, industry, universities, and state and local governments to demonstrate the SATS concept. Once this concept is proven, we can work cooperatively with state and local governments to transition this capability across the nation to benefit all of our citizens. SATS technologies have the potential of reducing inter-city travel times by half in many markets, while increasing ten-fold the number of communities served by air transportation.

IMPROVING SAFETY IN THE AIR TRANSPORTATION SYSTEM

The worldwide commercial aviation major accident rate (as judged by hull losses per million departures) has been nearly constant over the past three decades. Although the rate is very low, increasing traffic over the years has resulted in the absolute number of accidents also increasing. The worldwide demand for air travel is expected to increase even further over the coming 2 decades—doubling or tripling by 2017 with the estimated requirement for up to $1 trillion in new aircraft deliveries. Without an improvement in the accident rate, such a traffic volume could lead to 50 or more major accidents a year—a nearly weekly occurrence. Given the very visible, damaging, and tragic effects of even a single major accident, this large number of accidents would clearly have an unacceptable impact upon the public's confidence in the aviation system and impede the anticipated growth of the commercial air-travel market. The safety of the general aviation (GA) system is also critically important. The current GA accident rate is many times greater than that of scheduled commercial transport operations. With the GA market also poised to grow significantly in future years, safety considerations must be removed as a barrier if this growth is to be realized.

As is the case in system capacity, NASA has ongoing research in safety enhancing technologies for nearer term application in the existing air traffic system as well as more revolutionary technologies for improving safety. In the last calendar year, LaRC demonstrated several capacity and safety related technologies at the Dallas Fort Worth (DFW) airport.

Runway incursions, which are conditions where two aircraft are operating on the same runway, are a growing national concern. Incursions have more than doubled over the past 6 years. Last year, we saw a new high of 429 recorded runway incursion incidents. A technology demonstration in October 2000, at the Dallas Fort Worth Airport, illustrated new methods to eliminate two-thirds of these incursions, specifically those caused by pilot errors. If made reliable enough to warrant installation on aircraft, these methods would allow the crew to positively and independently verify which runway they were on and indicate the presence of any other aircraft either on, or about to use, that runway. This capability would go a long way to eliminate the serious threat of, and the tragedy resulting from runway incursion accidents.

A more revolutionary approach to improving safety involves providing a synthetic vision system for the pilot. Limited visibility leading to controlled flight into terrain is one of the greatest contributing factors in fatal airline and general aviation crashes. Last October, again using NASA's B–757, an early version of a synthetic vision system was demonstrated at the Dallas Fort Worth Airport. This type of system would use terrain data maps and, eventually, fog-cutting sensors to give the crew a clear-weather view of the world outside the cockpit no matter what the weather or time of day and thus eliminate controlled flight into terrain accidents. One evaluation pilot commented during a demonstration flight, "The terrain picture—the synthetic vision display—is just terrific. I find myself forgetting that that's not the real world I'm looking at." While a significant amount of effort is still required to make these systems a reality, they do represent a breakthrough for safe flying.

REDUCING NOISE

The projected increase in demand for air travel, coupled with our citizens' quality of life expectations require significantly improved aircraft noise reduction technologies. NASA's noise reduction program is focusing on three technical areas: engines, airframes such as landing gear and flaps, and aircraft operations. Major strides have been made in new approaches to reducing engine noise.

Not long ago, during the 1990s, as research limiting engine noise was being accomplished, airframe noise, the noise that the airframe itself makes as it moves through the air, was thought to be a barrier that would limit further overall aircraft noise reduction progress. Researchers at Langley and Ames took up this very difficult challenge, developed an understanding of the fundamental flow characteristics leading to the generation of airframe noise, and are now able to identify design modifications to substantially reduce airframe noise.

We have made significant progress, but public expectations are high, and our job is not done. NASA's ultimate goal is to develop technology to contain all objectionable noise within the airport boundaries. In this way we can achieve our citizens' expectations for their quality of life, for quiet neighborhoods and homes. Containing objectionable noise within the airport boundary will also enable the projected demand-driven increases for air travel to allow our citizens full access to all of the goods and services provided by our air transportation system.

REVOLUTIONARY NEW VEHICLES FOR A NEW ERA IN FLIGHT

Revolutionizing the airspace system alone is not enough. To meet the challenges of safety, noise, emissions and performance an entirely new level of vehicle efficiency, functionality and environmental compatibility must be achieved.

We stand at a unique time in technology evolution—a time where numerous advanced technologies have been developed or are on the horizon that will break the current "*tube with wings*" shape paradigm for aircraft. The significant advances in biotechnology, nanotechnology, and information technology are opening the door to a new era in aircraft development resulting in designs that will be radically different from today's aircraft. The continued viability of aviation is not through evolutionary or near-term approaches alone, but through development of revolutionary advances utilizing these emerging technologies.

As Mr. Goldin has pointed out, the aircraft of the future will not be built of traditional, multiple, mechanically-connected parts and systems. Instead, aircraft wing construction will employ fully integrated, embedded, "smart" materials and actuators that will operate more like a bird's wing. If we can emulate the characteristics present in nature, then we will be able to use these characteristics to develop revolutionary civil and military aircraft.

Rather than optimizing the vehicle shape for just one phase of flight (perhaps with some mechanical motion to achieve enhanced performance at a limited number of other conditions) we could have an aircraft which, like a bird, constantly changes its shape to achieve optimal performance at all flight conditions. Able to respond to the constantly varying conditions of flight, sensors will act like the "nerves" in a bird's wing and will measure the pressure over the entire surface of the wing. The response to these measurements will direct actuators, which will function like the bird's wing "muscles". Just as a bird instinctively uses different feathers on its' wings to control its' flight, the actuators will change the shape of the aircraft's wings to continuously optimize flying conditions.

Intelligent systems composed of sensors, actuators, microprocessors, and adaptive or neural controls will provide an effective "central nervous system" for stimulating the structure to effect an adaptive "physical response." The central nervous system will provide many advantages over current technologies. Proposed 21st Century aerospace vehicles will be able to monitor their own environment, performance, and even their operators in order to improve fuel efficiency, minimize airframe noise, and enhance safety. They will also have systems that will provide safe takeoffs and landings from short airfields enabling access to this country's more than 5,400 rural/regional airports.

Researchers at NASA Langley Research Center are exploring these advanced vehicle concepts and revolutionary new technologies.

NEW MATERIALS, ACTUATORS, AND SENSORS

Langley Research Center has made pioneering contributions in composite technology development. We have recently initiated research activities on the development of nanostructured and biologically inspired material concepts. These new classes of materials have the potential to mimic the attractive attributes of biological systems including self-assembly, self-diagnostics, self-repair, and multifunctionality. The emergence of computational material analysis capabilities will give engineers the ability to design materials to achieve the desired functionality leading to ultra-lightweight, structurally efficient aerospace vehicles. Using physics-based computer simulations, Langley researchers have shown that carbon nanotube reinforced composites have the potential to be three times stronger and four times stiffer than even the composite materials used on aircraft such as the B–2 stealth bomber and the Boeing 777. Such new materials could reduce the vehicle structural weight by about 50 percent and the required fuel by about 25 percent. The gains in a next generation reusable launch vehicle would be even more dramatic because the new nanotube reinforced composite material would be replacing conventional aluminum. In this case the predicted vehicle dry weight could be reduced by a factor of four. These materials are an enabling technology for developing a single stage to orbit reusable launch vehicle, which is essential in achieving the goal of reducing space launch cost by an order of magnitude.

All flying vehicles rely heavily on effective sensing systems to ensure the safety and control of the vehicle. Thus far we have developed fiber optic sensors that can be embedded throughout large areas of the aircraft skin for health monitoring. Recent breakthroughs in this sensing technology has allowed us to put hundreds of sensors on a single optical fiber and sense a spectrum of stimuli including temperature, loads, and the presence of hazardous chemicals. These fiber optic sensors have been deployed on several large structures including X-33 prototype cryotanks and full scale wing box test structures. For a recent wing box load test 3000 fiber optic strain sensors on only four optical fibers were used to provide high-density strain data over a large area with negligible weight penalty. Thus we are able to reduce the weight and complexity of sensing systems while increasing the number of places on the vehicle we can make measurements. We have also designed fault tolerant systems that are impervious to electromagnetic interference. These technology advances are poised for integration into an advance aircraft control system that mimics the human central nervous system. In addressing our future vision, we are developing concepts that will combine these technologies into an advanced control system that can respond to sensed stimuli and seamlessly adapt the vehicle to unexpected flight conditions.

In addition to sensing systems, aerospace vehicles also rely upon actuators for vehicle control. Langley researchers have used smart materials to develop embeddable actuators that can be used to control aerodynamic and structural motion. Two such actuators "Thunder" and the "MicroFiberComposite" actuators have won IR 100 awards. In the area of innovative structural control, we expanded the performance envelope of engines by developing structural concepts that change shape using advanced smart metals to reduce fuel burn and cost. We have also used Langley developed piezoelectric materials to control vibration on an F-18 model resulting in increased service life and reduced cost. For the future we are currently developing new smart materials that can be used to control and move the aircraft structure on command to continually optimize performance throughout flight.

AERODYNAMIC PERFORMANCE

To improve aerodynamic efficiency Langley engineers have conceived and demonstrated concepts for "porous" wings and small riblets on wing skins to dramatically reduce drag and improve performance. We have conceived new innovative concepts that allow us to effectively re-shape the wing of an airplane using micro devices to create a virtual new wing shape—one formed by both air flow and hardware. This micro-flow-control technology can improve the performance of aircraft engines, wings, and tails.

Langley has pioneered research in microflow control technology. Riblets are microgrooves on a surface, which when aligned with the flow, can reduce the skin friction drag. This technology was flight-verified for a 6 percent reduction in skin friction drag. Another technology called Passive porosity allows the skin to breathe and redistributes the pressure field to potentially control flow separation for improved maneuvering capability. The U.S. Navy used this technique on the F-18E/F to solve its' wing drop phenomenon. Micro-vortex generators (MVG's) are small wing surface devices that energize the flow near the surface to help prevent flow separation. Test results showed that MVG's dramatically enhanced aerodynamic performance including a 10-percent increase in lift, 50-percent decrease in drag, and a 100-percent increase in lift-to-drag ratio. During flight tests conducted in 1996 and 1997 by Gulfstream, the micro-vortex generators outperformed conventional vortex generators, and Gulfstream now incorporates MVG's on the outboard upper surfaces of its' airplane wings for enhanced cruise performance. With the MVGs installed, the Gulfstream V was able to achieve a higher maximum cruise speed, extend its operational range capability, and exhibit better controllability. The Gulfstream V aircraft has set numerous domestic and world speed and performance records and was named the winner of the 1997 Collier Trophy presented by the National Aeronautic Association.

New technologies are currently being pursued in active microflow control. Microactive flow control is a very multi-disciplinary integration of technologies including advanced aerodynamics, smart materials, advanced structural integration, and new system control theory. In the past flow control has utilized steady actuation techniques such as steady blowing or suction. Further advances are possible by utilizing pulsed or unsteady actuation devices. Unsteady devices allow aerodynamicists to accomplish the same performance benefits as steady devices at two orders of magnitude less energy consumption. An example of an active flow-control device is the synthetic jet, a device that acts like a tiny electrically driven pump. It consists of a vibrating membrane placed in a chamber below the wing surface. These devices can be very small and operate on the micro-scales of the vehicle to achieve macroscale results. As an enabling technology, active flow control technology benefits have not yet been fully explored. Langley is considering a variety of areas to apply these technologies to enable vehicles such as that portrayed in the NASA vision. These include active flow control in engine inlets to improve efficiency and reduce noise, new concepts for pneumatic flaps or ailerons to eliminate the need for existing high-lift or flight control surfaces. Other applications include drag reduction concepts, noise reduction concepts, and flight-maneuverability concepts.

HIGH SPEED FLIGHT

The value of time as a commodity is also evident in air travel over long distances. Intercontinental travel at current commercial transport speeds can be grueling and potentially unhealthy. The investments made to date by the U.S. government and industry have made the dream of a environmentally acceptable, economically viable supersonic aircraft nearly a reality. NASA is cooperating with DARPA to explore noise reduction technologies and low sonic boom designs. Langley engineers have also explored modifying the physical shape of the aircraft utilizing numerical optimization. These optimized vehicles demonstrate improved aerodynamic efficiency, and much lower sonic boom levels at supersonic speed. Continued effort is needed to explore new technologies in these areas, and others including improved efficiency and longer aircraft life.

TECHNOLOGY INTEGRATION

Although I've addressed four technological areas separately, the technological advances in one area often beneficially affect other technology areas. By integrating advanced technologies we feel that more efficient and adaptable aircraft are in our reach. This year we are conducting tests to demonstrate simplified flaps on aircraft using small synthetic jets with smart materials to control the flow over the wings. This technology blends advanced materials, control systems, micro electronics, and aerodynamics to enable shorter take off and landing, lighter weight flaps, and reduced fuel burn and noise. In the next several years we look forward to demonstrating concepts for dramatically improving the safety of aerospace vehicles using self-healing materials and electrical systems. We envision aircraft that are optimized to improve functionality for the entire flight regime specifically addressing safety needs while reducing fuel burn and noise. These technological advancements will benefit the breadth of flight vehicles from vehicles that fly in the atmosphere to space transportation vehicles.

Achieving the Goals

NASA's vision for revolutionizing air traffic management and developing revolutionary new aerospace vehicles is sufficiently ambitious to undoubtedly cause some to wonder whether or not it is achievable. Efforts of this level of difficulty represent the proper role for NASA, which is to undertake activities beyond the risk limit or capability of industry, and to deliver validated technologies. My belief is that the goals inherent in the vision are achievable. The belief is based on both on our long-term track record and on the recent, demonstrated progress made toward achieving our goals.

It is imperative that we aggressively pursue attainment of the technology advances required by the vision. The pace of technology development is increasing very rapidly and the only way to achieve world leadership in an area is to out run the competition. Moreover, one of the most effective ways to maintain and increase the quality of life for our Nation is to provide for the enhanced safety, efficiency and environmental compatibility of our air transportation system as quickly as possible. NASA is uniquely positioned to conduct the research required to develop revolutionary new air vehicles and a revolutionary new approach for air traffic management. We do not believe, as some might suggest, that these are maturing areas of technology. We believe that our 21st Century future is as full of promise today as was the 20th Century to our predecessors.

We are accomplishing excellent, high-payoff research activities that will benefit the quality of life in the country through enhancements in safety, airspace system capacity, noise and emission reduction and contributions to the pre-eminence of military aircraft.

Hard choices have been and are being made. The NASA Aerospace Technology Enterprise has reprogrammed a significant portion of its research funding to enhance efforts to achieve the highest priority products. The reprogramming efforts have taken place within our existing funding and have thus necessitated stopping some ongoing efforts. The agency is also emphasizing aerospace research rather than Aeronautics and Space activities to help achieve all the synergies that are available. The Agency has embarked on a detailed study to determine which facilities it requires for the future, to eliminate the facilities it no longer needs, and to ensure it has adequate funds to maintain and renew the facilities it requires

Hearings such as this one today will help the country with this debate, I am happy to have been able to contribute some input to the discussion.

Senator ALLEN. Thank you, Dr. Creedon and Administrator Goldin, both of you. We probably could listen to you for an hour each.

Let me ask some questions here. I will go first and then turn it over to Senator Breaux.

For Administrator Goldin, I had many things I was going to be asking you. I will be looking forward to that blueprint, which will be, I think, very important, because, clearly, NASA has a lot of multiple centers where the research is going on. You have to get them all working somehow together and a maximum utilization of those capabilities of the skilled people as well as the facilities.

One thing that I think would be helpful, if you could, when you come up with your blueprint of how you use your research centers, how do you measure? Fortunately, you have been at NASA for a while, so you do not have to get up to speed. You understand the challenges. How do you measure the value of investment, taxpayers' dollars, budgets, appropriations? How do you measure the value of the decisions you are making between aerospace, space, aeronautics, and so forth? How could we measure the performance, the investment, the bang for the buck? What is a measurement that we could utilize?

I think we all recognize this research and development needs to continue. We are behind. The statistics that Congressman Goode and Senator Hutchison brought up about falling behind as far as the world market, we are competitive folks and we want to get back ahead and start doing it in a reasonable way, but how do you have an objective measurement that we could look at to say this is worth it, these billions of dollars are doing, A, B, C, or whatever unit measurement you would have?

Mr. GOLDIN. In most of the areas of NASA, in fundamental science, we could take a look at a number of different measures, but one is how many papers are published, how much fundamental knowledge have we generated.

In the area of aeronautics, it is a little different.

Senator ALLEN. Right.

Mr. GOLDIN [continuing]. Because there it is very specifically public good in two primary areas. One, for the military, have we had an impact on the future defensive capabilities of the Nation? There, the best judge is the Department of Defense. In the area of commercial aviation, there are two areas where we could have an impact. One is in our interface with the Department of Transportation and how effectively have we developed technologies, transferred them to the Department of Transportation and the companies building the equipment so they could be certified, and over the next decade, did we help the Department of Transportation increase their capacity 30 percent—I am throwing that number out here today—and cut delays by 50 percent?

Now, clearly, we have to make sure that the Department of Transportation has the adequate funding in their budget to fully implement the things we are developing, and, by the way, we do have these 16 technologies fully documented. I did meet with Secretary Mineta, and in the next few weeks, Administrator Garvey and I will be sending a letter to Secretary Mineta clearly calling out the things that we could do.

Then, how well do we come up with a revolutionary system, we have a vision for that. At the present time, the old system has thousands of individual segments that have to be tracked. It is very cumbersome. It has been in place for 50 years.

The new system needs to be measured, and we could give you a measurement by showing you how different technologies apply against our simulation tools in the next few years. You could track us. You could see where it goes.

My final point is, in the area of commercial aircraft, America now has only one long-haul jet transport company, Boeing. We have two engine companies, Pratt-Whitney and GE, but, in addition to that, we have a general aviation industry, and Mr. Bolen is going to talk to that industry.

Just 7 or 8 years ago, that industry was down to 600 planes a year. They are now back to 1,000 and 2,000 planes a year, and we took a goal that within a decade, they will be selling 10,000 planes a year. You could measure us.

We have been working with them on technology. There are a whole host of new planes coming out, Highway in the Sky, glass cockpits, and these are going to make a huge difference. You need only go to the air show in Oshkosh each year to see the impact NASA is having on general aviation.

And, finally, not just the planes, but we have to measure and work with each State in this Nation to implement the small air transportation system. We have a demonstration program, and in the next few years, we will measure that and report to this Subcommittee. Within a year or 2, I think it will then become time to see how whether the Department of Transportation or NASA or some other funding agency ought to be implementing that approach. It will revolutionize life in America.

Those would be my measurables.

Senator ALLEN. Thank you, and we look forward to following and working along with you in that regard. Thank you for a very insightful and convincing answer.

Dr. Creedon, some of the practical developments that have come from NASA-Langley, such as detection of wind shear and the reduction of the noise footprint, in particular, are all very important for commercial as well as some of the military jet bases. Do you have any insight as to what we could do better or if there could be any help from the Congress insofar as a commercialization of any of the developments or spinoffs from your research there at Langley? Is there anything that Congress could do to be more helpful to you in the commercialization of——

Mr. CREEDON. Do you mean in non-aerospace areas?

Senator ALLEN. In aerospace, aeronautics. Well, yes, and if you could explain or share with us some indirect benefits from your research.

Mr. CREEDON. OK, certainly. At NASA-Langley, we judge our effectiveness to the extent to which people actually use the research products that we come up with. So that, any activity that we undertake, whether it be long term, as the Administrator has described, or somewhat nearer term, our objective is to have the technology that we come up with used by someone. In fact, there is virtually no civil or military aircraft flying today that does not have some technology in it that came from NASA Langley Research Center.

As far as commercialization, there are really two aspects of that. One is in the aerospace industry, and the other is spinoffs, as you called it, into the non-aerospace area.

Let me address the latter one first. We have a very aggressive program to spin off the technologies that we come up with into the non-aerospace area. We have come up with technologies that have been able to ameliorate some of the effects of diabetes. We have come up with technologies for aerospace application which, when put to a novel use, could serve other purposes in the health arena. For example, we developed the sensor to develop the ability to very minutely detect turbulence of air. This turns out to be very, very good in application of fetal heart rate for pregnant women, and with that, actually the fetal heart rate can be sent over a phone line so that the woman does not even have to enter the doctor's office.

We are finding that we have the tools that we need to do a very effective job in that. So I am not sure that in that area we really need any additional help from the Subcommittee.

In the main transfer of our technology to aerospace activities, as I said before, that is why we exist is to take the technologies, and we have set our goals to be that we measure our success by the extent to which it is used. I think we have been very effective in that area. So, if there is help that we need, it is probably not in the area of additional ways to make this possible.

Senator ALLEN. Thank you very much.

In fact, I think it may have come from you. I was just speaking to the president of VCU, and I believe NASA-Langley somehow has been working with the military for telemedicine. Was that something that was started at NASA-Langley? When you were going into the fetal heart rates of phone lines and diabetes detection, was that something that came from——

Mr. CREEDON. From NASA-Langley, yes, it did.

Senator ALLEN. It did?

Mr. CREEDON. We are working very closely with VCU. Mr. Sam Morello of NASA-Langley is on a committee that is helping. He is in charge at Langley of taking aerospace applications and seeing that they get useful application in the non-aerospace arena, and he is working with VCU on that project.

Senator ALLEN. As I understand it, telemedicine—in particular, as a military application, say someone is on the battlefield or out at sea or wherever they may be, not near a hospital, but needing the expertise and proper diagnosis and prompt treatment—actually came from you all.

Mr. CREEDON. Well, the particular VCU application. There are a lot of efforts in telemedicine, and there are other NASA centers that play a major role in this area as well. The particular application that we talked about did come from NASA-Langley, but there are many other applications within NASA.

Senator ALLEN. Thank you very much.

I would like to turn it over to Senator Breaux for any questions he may have.

Senator BREAUX. Thank you, Mr. Chairman.

I thank the panel members for their testimony.

Let me try to figure out where we are. The briefing memo says that the fiscal 2002 budget request for aerospace technology is $1.36 billion, a $120-million increase over fiscal year 2001. I take it that in research and development, that your aeronautics research is included in that part of the budget?

Mr. GOLDIN. Yes.

Senator BREAUX. I am trying to find out how much is available for aeronautical research and development.

Mr. GOLDIN. The budget number I recollect is $1.5 billion. I do not recognize that $1.36 billion. Let me just double-check here.

Senator BREAUX. It says the fiscal year 2002 budget request for aerospace technology is $1.36 billion, a $120-million increase over fiscal year 2001, and NASA's aeronautic research is included in the aerospace technology program. I am trying to figure out, are we doing less or more?

Mr. GOLDIN. OK, I got it. The full budget for the enterprise is $1.5 billion, but that leaves out some commercial activities.

The Authorization Act of 2000 told us to merge our technologies in launch and aeronautics. It is very hard to pull the two of them out. For example, if we work on materials and structures, if we do it separately for aeronautics and separately for launch vehicles, we are doing work that is going to be wasted. If we do work on avionics, if we do work on nanotechnology, it is hard.

Senator BREAUX. So the private sector comes up and says, "Look, we are really dependent on aeronautics research by NASA, and we are concerned that they are going to be spending less than they did last year. What is the answer?

Mr. GOLDIN. The answer is I think with this year's budget, in effect, we will be spending more, but it is not on the things that we used to do, and let me give you some examples.

With any budget, we had no huge rises in the NASA budget. We had to make tough decisions: Should we work on things that are near term and evolutionary, or should we work on revolutionary things? We made a decision to cancel the rotorcraft program. I know there are some very unhappy people in the rotorcraft program, but the fact of the matter is we have been working on this for a long, long time, and with the exception of making them a little quieter and making rotorcraft a little faster, we have achieved our primary goals and it was time to do something different. So we decided to cancel that, and we put that money into nanotechnology in advanced systems like we showed here.

We freed up $730 million by canceling a variety of programs that we felt were not cutting-edge and fell into an area that got closer to product development than basic research.

Senator BREAUX. What was the reason for terminating the X-33 project?

Mr. GOLDIN. The X-33? We had to make a basic decision, could Lockheed Martin give us additional work that merited the additional money. They were in a competitive activity, and their proposal did not measure up to other proposals. It was a significant amount of money that—I cannot answer that question.

Let me say that after we make the final source selection in the Space Launch Initiative, it might be more appropriate for me to answer that, but the basic bottom line that I can say today, Lockheed Martin did not give us value-added for the amount of additional money they proposed. We signed a contract with them for $930 million. They put in about $300 million, and they required a significant fraction of the additional money that we put into the program to go ahead and just do a test launch on that vehicle, that it was at a much lower speed, and it did not meet the kind of technical criteria we were looking at. So it was a very tough, hard decision, and right now we are working with the Air Force.

I just sent a letter to General Eberhart today to see if we could hand over that technology to the Air Force, that has a much less demanding mission than NASA has, to help transition it.

Senator BREAUX. Have you all had discussions with DOD on that proposal? I know you all probably just did not ship it over there without making some inquiries as to whether they would be interested in receiving it or not.

Mr. GOLDIN. I have had discussions with General Eberhart who is CINC Space, and we are going to be setting up a series of meetings. We will be getting together over the next month or two, and we are going to try and see if there could be value-added for the taxpayer to do it.

But the dilemma we have at NASA is our budget did not grow over the last decade. It has been flat. In fact, I would like to show you a chart here to show you why we have to make tough decisions.

Could I have that budget chart?

Senator BREAUX. We did not rehearse this.

Senator ALLEN. No. That is a good leading question.

Mr. GOLDIN. This is a normalized budget to 1993. So in 1993, which is at the extreme left, you can see a one. NASA is the blue curve, and it dropped below one up until the year 1999, and then it came up, and we are back where we started when I came to this agency, in effect, at about $14.5 billion. The green line is the defense budget, which is up about 15 percent, and that orange line is the other non-defense discretionary spending, which is up 37 percent. NASA, unlike almost any other agency in the government, where we have to launch things in space and they have got to work, have been given a flat budget. When you get a flat budget, you do not make popular decisions to make people happy. You live within that budget as it is given to you.

If we were blessed with more money, we would know how to spend it. Given the constraints of that budget, I think we have done a phenomenal job. We have tripled the number of launches and divided by three the cost per spacecraft. We took $1 billion a year out of the shuttle and it is four times safer. We have people in space right now building the space station. So all I can say is it was a tough, hard decision on the X-33, but we could not afford the additional money that the Lockheed Martin Company wanted, and we could not justify the additional dollars against the marginal improvements they give us in performance. That was the dilemma we had.

Senator BREAUX. May I have one final comment and question. I guess what is a wake-up call—or it should be to this Congress and to this Subcommittee and everyone—is what the Europeans are telling us they are getting ready to do. They are preparing to invest a public and private combination of funds that amounts to approximately $95 billion. Here in this country, we are looking at, by some estimates, a reduction of over half-a-billion dollars over the next 5 years in aeronautics research. I am not sure where that is going to leave this country in that particular area. If we are going to be looking at long-term research, and near-term research is going to the left up to the private sector, without any public-private partnership, how can we compete?

Mr. GOLDIN. Well, first, if the Europeans are going to make small, marginal improvements with what we are seeing here, we will whip them. Money is not the magic ingredient, the partnership is. It is absolutely clear. We have been talking to Boeing and working with Boeing, and I think it's important you talk to the Boeing representative, David Swain, here today. We have been talking to Pratt Whitney and GE, who are the backbone of our commercial aviation.

They do not want us to do the near-term things that will impact the next 5 years. The die is cast for the next 5 years. The things we have already done are into their products, and we are now looking what can we do now for a decade from now. If you look to NASA to impact the sales of Boeing planes and GE engines and Pratt Whitney engines in the next 5–7 years, the die is cast. What we are talking about is moving out aggressively in a real partnership.

One of the other problems we have, Senator Breaux, is that there is a misconception about what NASA does in aeronautics. We almost lost that program a couple of times. There are certain independent groups who call what we do corporate pork. They make very strong inroads and they call it corporate subsidy, and they do not understand the criticality of what NASA does to the defense of the Nation and the criticality of what NASA does for the critical companies, like Boeing, Pratt Whitney and GE.

Year after year, a lot of people from these outside organizations made unbelievable gains with the people, over in both Democratic and Republican administrations, they do not understand this criticality. That is another reason for the downward pressure on our budget. It is very, very tough.

As I said, this hearing today—the people at NASA were cheering when we got the call, that we actually had a hearing. It is the first time in this Senate in about 9 years that we have had such a hearing. So we need to face these issues and we need to work it as a Team America. We need to work with academia. We need to work with the large and small companies, long-haul jet transports and general aviation, with the States, to get this new transportation system in. One of the biggest problems Boeing is facing is how do you sell planes when there is gridlock in the airways? They are worried about it. Boeing set up a whole new organization that is trying to deal with air traffic and the airspace system. So it is complicated, but my point is if we have a vision, Team America always comes across, and honing that vision and then seeing how we address the resources in the next year or two is important.

But another measure, Mr. Chairman, is when the industry cost-shares with us. One of the reasons that the NASA budget came down a couple of hundred million dollars a year is on the high-speed civil transport program, the Boeing Company said, you know, because of the market pressures, we will not have money available for the next two decades to do revolutionary planes, and they were going to cost-share with us literally billions of dollars.

So when our industrial partner came to us and said, "Look, we have got to get supersonic shocks suppressed over land, this program will not do it just yet, and we have got to build lightweight engines with small diffusers so we can meet the Stage 4 noise requirements, this program will not do it, we step back. So another measure of the partnership is the money going in, and in talking to Pratt Whitney, GE and Boeing, looking at a futuristic program like that, where the government does the high-risk, high-payoff research, and then transitions to industry, they say that they are interested. So it is a complicated thing, but it will not happen in the next 5 or 10 years. The die is cast.

Senator ALLEN. Thank you, Senator Breaux, and thank both of these gentlemen for your very insightful, passionate, and eye-opening comments, and thank you for the other aspects of it. It is good that Senator Breaux asked you that question so you could show those charts to us.

Mr. GOLDIN. I was hoping he would.

Senator ALLEN. Even if he did not, you found a way to make that part of the answer, but that is perfectly, perfectly fine. That is the reason for this hearing, for us to be more informed. Senator Warner has come back from the Foreign Relations Committee. I know he may want to make a statement. I was wondering why you were going to Foreign Relations.

Senator WARNER. I am conducting another hearing.

Senator ALLEN. If you would like to make a statement——

STATEMENT OF HON. JOHN W. WARNER, U.S. SENATOR FROM VIRGINIA

Senator WARNER. Just a very short one, Mr. Chairman, and I thank the Ranking Member. Twenty-three years ago, I was a Member of this Subcommittee, and I must say I regret having moved on elsewhere, but anyway, I am glad to be back again, and seeing you in the chair is a very special privilege for me. I just wanted to say to our good friend here, Administrator Goldin, and to Dr. Creedon, how much I appreciated your coming to Virginia. I presume Congressman Goode addressed—has spoken to that event, and I was a part of it, so I will not go into more details. But it was an extraordinary day, not only for my State, but I think for civil aviation and the alleviation of the congestion, and I am just going to ask that my statement be put in the record, Mr. Chairman.

Senator ALLEN. Without objection.

Senator WARNER. But over the past several years, Administrator Goldin and I have had a very friendly discussion on the allocation of funds between aerospace and space, and despite the fact that we are privileged in Virginia to have Langley, I have taken an objective view about it, and I have visited Langley and I have talked to many of the people involved in the aerospace industry. I have to say I presume you have covered the decline in the spending levels in the aerospace sector, Mr. Chairman. I do not wish to go over it, but——

Senator ALLEN. That is all right. Administrator Goldin mentioned it in a more general sense, but just a sub-category.

Senator WARNER. Am I correct, Administrator Goldin, in this statistic which my research reveals, that the Federal funding for NASA's aeronautical research is only 40 percent of what it was 4 years ago?

Mr. GOLDIN. I do not know if it 40 percent, but I can tell you it is about $200 million a year less.

Senator WARNER. Well, all right. I have to say to you, and I say it most respectfully. I have the greatest personal admiration—and professional—for you, but we do have our differences of views. This Nation is in the grip of the most extraordinary problems associated with the commercial aviation industry, and I will not enumerate them. I presume this hearing has covered some of those problems. I just have to ask you, as an old trial lawyer, I think the burden of proof is on you to show that this very significant reduction in your budget for aerospace has not been a contributing factor to the problems being encountered today by our traveling air passengers.

Mr. GOLDIN. I would say, in fact, that we have gone more than the distance. Let's take the aerospace system, which I think you are referring to. Five or six years ago, we at NASA became concerned about that, and we proposed a program of $480 million, called AATT. I cannot remember what it stands for, but it is advanced air traffic control systems. Based upon the work we have done there, we developed 16 new tools, decision support tools that we have tested in some of the airports around the country. In fact, Senator Hutchison was here, and we tested one of the tools that allows the air traffic controllers to vector planes into the airports. It increased the capacity by 10 percent at the peak travel period and saved $9 million a year at Dallas-Forth Worth. We are testing a number of these tools around the country.

The issue is does the Department of Transportation have the budget to transition these tools and certify them and then distribute them around the country? So from a technological standpoint, I will stand before any trial judge in this country, anyone who wants to ask me the question. We reprogram that money out of space resources, and when we reprogrammed the money, there were those that did not want us to do it, because the question was why is NASA, not the FAA, developing technology for air traffic management? At the present time, I just had a meeting with Secretary Mineta, and we talked about the fact that we need to have a near-term and a long-term approach.

In the near-term, we have proposed 16 different tools that, if we are successful, fully implemented, we could increase the capacity 30 percent without building one new runway, with information systems, decisionmaking systems and sensors, and we think we could accomplish this if there is adequate funding to implement these tools within the next 7 years.

Senator WARNER. I think that is exemplary, and it is an example of one program, but with a 60 percent reduction, could there not have been other programs brought to bear? I think the entire Federal Government should go to, as we say in the military, general quarters about the plight of the civil aviation industry. We cannot shift this heavy traffic to the already congested streets and highways of America. They are clogged and practically stagnated, particularly in our region here in the greater metropolitan area. So we have to rely on our air transportation to alleviate the congestion in surface transportation, certainly the automobiles.

So I plead with you to revisit whether or not the cuts have been too severe on the aeronautics side of your house. Space is exciting. It is every child's dream to participate someday in this. But at the same time, the parents are struggling to meet their daily commitments, whether it is family, work or whatever, in terms of surface transportation and in air transportation. Maybe we just better pace ourselves a little bit in space and stretch it out, and rebuild our transportation system here on Earth, so that we can coexist and live and enjoy a better lifestyle.

Mr. GOLDIN. I am with you, but I say there are other elements besides increasing the budget. We are developing a relationship with the FAA and the Department of Transportation that was essential. And I will say in open—5 years ago, there were some folks in the FAA that went to the Congress to try to cancel the half-billion dollars that we tried to reprogram because it was a bureaucratic problem, but we have worked it out.

The point I made before you came in, and I showed a chart, NASA's budget total has not increased a nickel in 9 years. Non-defense discretionary spending has gone up 37 percent, and in spite of the problems that DOD is having, their budget went up 15 percent. We have had to live with making hard decisions, and in making those hard decisions, I think with the budget we had, we did the right things. We are going through a transition. There is only one airframe manufacturer left in America. So the problem is more than the issue of NASA. There is no competition among American companies and Boeing has chosen to go the evolutionary route for the next few decades. NASA cannot change that fact of life, that they have made a business decision, and we respect it.

We were working on a high-speed civil transport. Boeing was putting in significant money into that. They had market pressures from Airbus, which caused them to say, "We better focus on the near-term." So they made a decision that we concurred with. We were putting in a billion dollars over 4 years into high-speed civil transport. When they backed out, we had no industrial partner. So all I am saying is we recognize that. We want to look into the future, but we are going to have to do some radical things to help the American aerospace industry, and we have begun that restructuring with Boeing. We have begun talks with Pratt Whitney and GE, and we are looking at not making three and 5 percent improvements in fuel efficiency; we are now talking about 25–40 percent improvements in fuel efficiency, so we could go take on companies like Rolls-Royce, which are selling engines like commodities.

So it is a broader issue than just adding the money, and this is why we would like to work with this Subcommittee and the companies and academia to address the problem. If we were to get just a few hundred million dollars a year, I am not sure by ourselves we would spend it wisely. But if we sat down with the industry and academia and set national goals over the next year or two, we could make a huge difference. The other issue that has really hurt us is if you go back to the 1970s, late 1970s, GE sold 70 percent of their engines to the Department of Defense. Today, they sell about 20 percent of their engines to the Department of Defense. So where they had that huge momentum of the high-tech defense budget, they now do not have it, and they could make an improvement in the engine. They spend a few billion dollars, and it takes them 20 years to get a payback.

So the market conditions have changed, and one of the concerns we have at NASA is, for the future defense of the Nation, if we do not strengthen the commercial sector, it is the commercial sector where the high-volume production is going on, that is going to come back and impact defense. I met with Secretary Rumsfeld about it. I expressed my concern about it, and that is why we are developing a blueprint between now and September, to see how we could work with the Department of Transportation and the Department of Defense to come out with a vision for Team America, and then I think it is time to talk about money.

Senator WARNER. Well, I respect your views on this, and you are better informed than I. This is not an area in which I spend a considerable portion of my time. I do on defense, and I know what you mean about the cutbacks in those engines by GE. That is because for 13 consecutive years, we reduced the defense budget, up until a year ago, when it was turned around, and I think President Bush is now going to further enhance the defense budget, after you take certain important preliminary steps of analysis of the department. But I come back to this question: We are now, as of the last year and this year, facing an exponential problem in civil aviation, of a multifaceted nature, and I simply say, with all due respect, if you could increase your budget in the aerospace part of your responsibilities, it would be my hope that that would be contributory to alleviate this problem.

I had not heard problems—such as those we are learning about today—3 years ago, 4, 5 or 6 years ago, at the time you were declining in these budgets toward aerospace, but they have suddenly started now and they are very, very serious, and could be life-threatening to the ability of this country to once again have a resurgence in its economy, which I am hopeful will take place under the administration of our President in due course. I thank you for respectfully listening, and you know you and I will always be able to do business together. You do a good job. I appreciate it. Congratulations on your most successful results in space. It is quite astonishing.

Thank you, Mr. Chairman.

[The prepared statement of Senator Warner follows:]

PREPARED STATEMENT OF HON. JOHN WARNER, U.S. SENATOR FROM VIRGINIA

Thank you Chairman Allen.

Mr. Chairman and Members of the Subcommittee, thank you for allowing me to testify before you on this very important subject—NASA's aeronautics research programs.

First, I would like to commend Administrator Goldin—he has been doing a very fine job.

As you all know, the NASA Langley Research Center in Hampton, Virginia, is a world-class center for aeronautics technology that helps the United States maintain and improve its position in commercial and military aviation. NASA researchers are currently developing technologies to make aircraft safer, quieter and more energy efficient. Unfortunately, federal funding for NASA's aeronautical research is only 40% of what it was 4 years ago.

I believe the United States stands at a crossroads in the development of our transportation network. Our air transportation system is *at*, *near*, or *over* capacity—take your choice. Congestion, delays, and cancellations are all too familiar to anyone who flies. NASA's aeronautical research is providing the technology necessary to help relieve these growing problems. But, I believe, it can do more. The dedicated people are in place—they stand at "the ready" to do more. The increase in funding allocations within NASA is the focal point!

Here is a fine example. I was recently at the Danville, Virginia airport with my colleague, Congressman Goode, to witness a demonstration of the NASA "SATS" program: the Small Aircraft Transport System.

This is a program that shows progressive and innovative thinking. I applaud Administrator Goldin for this program. NASA's SATS research is intended to develop navigational technologies that will help relieve congestion in our nation's overcrowded skies. It will allow citizens to fly using the under-utilized small airports and the growing fleet of small aircraft as an alternative to flying on overcrowded commercial airlines.

SATS research will focus on small airports without total reliance on air traffic controllers and on small, private aircraft. This type of innovative solution could help relieve the pressure on the hub and spoke air transportation system and create increased access to rural communities.

Mr. Chairman, and Members of the Subcommittee, thank you again for allowing me to speak to you on this important issue. The aeronautical research performed by NASA is critical to maintaining the United States' position as a leader in aviation for commercial and military aviation. I urge the Members of this Subcommittee to support this important research.

Senator ALLEN. If you would stay here, the questions that Senator Warner raised, and some of them in answering—one of the reasons none of this has ever been raised before is Administrator Goldin says there has not been a hearing in the Senate for 10 years, to have a decision on this, for the Senate to understand it, direct testimony, cross-examination and so forth. Now, from what Senator Warner said in his cross-examination or questioning of you, the way that you see the United States beating the Europeans is with this morphing-wing plane. Is that your revolutionary approach—how we will compete and kind of leapfrog over the Europeans? Was that what you were saying?

Mr. GOLDIN. Well, let me say it a different way. Boeing has announced they are going to build this subsonic cruiser. They do not have time for technology developments.

Senator ALLEN. I understand. They are going to be evolutionary.

Mr. GOLDIN. So there are a whole variety of techniques. We need to get the engines to be, not 3-to-5 percent more fuel efficient, but 25–40 percent more fuel-efficient. We need to figure out how to reduce drag. Right now, we have an airframe on a plane that is the same as the 707 was, almost 50 years ago.

Senator ALLEN. Is this research between NASA and GE, or Pratt and Whitney?

Mr. GOLDIN. It needs to be a team research, and it needs to be where NASA does the leading-edge work. I came from corporate America. If I ever went in to the chairman of the board and said, "Boss, I need a billion dollars, and I have an idea that we may hit with 50 percent probability, to improve the fuel efficiency by 25 percent, see you in 10 years," could not be done. That is what government needs to do. So we ought to do the front-end research, and at a reasonable point of majority, hand it over to GE or Pratt Whitney, preferably both. With Boeing, we need to look at new ways of building wings, new tools, so they can get the cycle time down by factor of two. The cycle time is too long for building planes.

In the automobile industry, they have got it down to a year, a year-and-a-half. In spacecraft, it used to be 5 years. Boeing, their commercial communications and spacecraft division is now putting out spacecraft in 12–14 months. That leaves the cost—getting to penetrate markets. So we need design tools, we need new technologies, and these are the things that we need to be working on, and that is the government's role. So if we, NASA, were to go off by ourselves, I think we would be baying at the moon. But NASA, working with the leading American companies, doing things they cannot afford to do, having a commitment from them that they will transition it and pick up the transition costs and prioritize it, is, I believe, the key. We need to engage the universities, because of the lack of young people going in. So it is those three things, and that is why I came back to the word Team America.

Senator ALLEN. I wish Senator Warner were still here, but he was talking about the difference—how much you allocate out of the pie going to NASA. How much goes to space and all the different components of space, whether it is manned, unmanned, Mars and all the rest, aerospace versus, say, aeronautics? How do you determine what is the appropriate level, out of that whole budget going to NASA, as to what should be going to, say, aeronautics research versus space?

Mr. GOLDIN. Well, we thought we had a good equation, up until about 3, 4 years ago, when the bottom started falling out. It just happened a little bit at the time, and we allocated a significant amount of money to focus programs, which we did with the Boeing Company, Pratt Whitney, GE Company, and then to basic research. Our basic research program is about the same, but our focus programs have changed. Given the situation we have now, I believe we are going to have to take a relook at it, and I would like to be able to throw a number at you, but I am hesitating, because we need to know where the DOD is going.

They are a major player in this. Right now, there is not a major new engine program on the books at the Department of Defense. After the joint strike fighter, there is not a major development program on the books at the Department of Defense. So if we go off by ourselves, we are not going to help anyone. In a similar manner, the Boeing Company is now developing their strategy for the 21st century. For NASA to go to tell the Boeing Company, that is going to be the ultimate beneficiary, "Here is what you ought to do," is the wrong thing.

So, in a hearing, it would have been easy for me to say let's do A, B, C, D, but I think we are going to have to take the time, given the change in the marketplace, given the threat from Europe—and by the way, the Japanese are absolutely determined to get into the aeronautics business 10, 15 years from now. So what we need to do is set our vision out 10, 15 years, divvy up the work so NASA does its front-end in partnership with the DOD, have a commitment from the engine companies, the avionics companies, the companies that do air traffic management, the general aviation industry, so we all know our roles and NASA does the leading-edge work, and we have those handover points. I think this is going to take a year or two. It will not happen in months, and I wish I could give you a better answer, but that is the only honest answer I could come up with, and it is going to take the House, the Senate, the administration and the parties involved, over the next year or two, to sort this through.

I view this as—I did not want to use the C-word—but I view this as a very serious challenge to America, and 10, 15 years from now, if you are 10–20 percent of market share and a crisis breaks out, and we do not have the kind—we used to have 45 programs. When I was going to high school, this Nation had 45 aircraft programs. Today we have one, in the government, the joint strike fighter. So if commercial is going to carry the day, it is crucial that we have a national strategy on commercial. That is why I am hesitant to say. I could give you this answer, that answer. It would be easy now. It would be popular, give us more money, but in the end, I am not sure it is the right answer.

Senator ALLEN. Thank you. Thank you. It is nice to hear a government administrator giving such a statement. I am sure President Bush is pleased, as well. Thank you, both of you, Dr. Creedon, Administrator Goldin, so much for your very probative, insightful testimony. It is not going to be another 9 or 10 years, if I have anything to say about it. This Subcommittee will be working with you on the NASA budget authorization, as we go into budgeting in the years to come. We look forward to working with you and we appreciate your very credible leadership. Thank you.

Mr. GOLDIN. Thank you. I will submit in writing answers to Mr. Goode. I thought they were excellent questions. I think they are very, very deserving of an answer, and I know you need to get on with the rest of the hearing, but for the record I will submit formal responses to them.

Senator ALLEN. Let it be said that both gentlemen submitted testimony. Your testimony, as submitted, will be made part of the record, and in the event that other Members of the Subcommittee or committee have any questions, I hope you will be willing, which I know you will be, to answer their questions in writing. Thank you both. Thank you, gentlemen.

Mr. GOLDIN. Thank you for holding this hearing.

Senator ALLEN. You are welcome. Let us proceed with our second panel. The order that we have it, unless you wanted to speak in a different order, is Mr. Ed Bolen, President of the General Aviation Manufacturers Association; Mr. Dennis Deel, President, Lockheed Martin Space Systems, Michoud Operations; Mr. Roy Harris, Jr., Chief Technical Adviser, NASA Aeronautics Support Team; and then, cleanup hitter, David Swain, Senior Vice President, Engineering and Technology, and President, Phantom Works, the Boeing Company. Is that OK, gentlemen, in that order?

We would first like to hear from Mr. Bolen, who is, for the record once again, President of the General Aviation Manufacturers Association.

STATEMENT OF EDWARD M. BOLEN, PRESIDENT, GENERAL AVIATION MANUFACTURERS ASSOCIATION

Mr. BOLEN. Thank you very much, Mr. Chairman. It is an honor to be here today. As has been said by you and others so far today, the U.S. is the undisputed world leader in all aspects of aviation. The benefits that come from that include high-paying, good manufacturing jobs; a positive impact on our Nation's balance of trade; and the largest and the safest air transportation system in the world.

I think sometimes these benefits can be taken for granted. However, I think the other countries that have looked at the United States clearly recognize what we have, and they have decided that they want that for themselves. It is evidenced by the Europeans' 2020 statement, which has been mentioned so far today several times.

I will say that U.S. companies are not just giving up their preeminence lightly; U.S. manufacturers invest very heavily in research and development. Over 10 percent of our sales revenues go into R&D projects. That is an extraordinary commitment. According to the U.S. Department of Commerce, other industries and other manufacturing companies typically spend between 3–4 percent of their sales revenues on R&D. So U.S. aviation manufacturing companies are extremely committed to new technologies, to research and to development. But private sector investment alone is not enough. NASA's research programs are absolutely critical to our ability to remain the world leader in aviation.

We need the basic research that NASA is doing. Armed with it, private sector companies can then invest millions, even billions, of dollars, and take that basic research and turn it into the development and application of new products for the marketplace. NASA's proposed aviation budget, as has been talked about today, is about half of what it was just a few years ago. It is at an historically low standard, and that is a mistake. We should be investing more, not less, in NASA's research programs.

There are a number of NASA aviation programs that are critical, not just to the aviation community, but to our Nation as a whole, and I think they have been touched on a little bit today. Senator Warner talked a lot about capacity and the situation we have, where our roads are clogged and our commercial hub airports are crowded. NASA has a program called SATS, the Small Aircraft Transportation System, that looks at trying to enhance the use of general aviation to alleviate some of that congestion on the highways and in the commercial airports. It is a very positive program that we at GAMA are very excited about.

General aviation is a mainstream form of transportation, but we can do more to utilize its benefits, and some of the technologies that they are working on in SATS, including the Highway in the Sky, some of the synthetic vision programs and so forth, are really positive and can really increase the use and utilization of general aviation as a way to alleviate some of our capacity problems. They also have the program that was touched on earlier—it is called AVSTAR—and they use it to do complex air traffic control modeling, to help us better understand traffic flows so that we can find efficiencies and increase capacity from changes in procedures.

Another issue that was touched on, obviously, it is not enough just to increase capacity. We want to improve safety, and NASA is doing work in that area. Their entire aviation safety program is along those lines. The AWIN program helps safety in terms of better understanding the weather, better matching weather conditions to pilot abilities and airplane capabilities. They have programs to enhance vision, to help us see better through different types of weather. Weather is a primary cause of accidents in aviation. Helping us better understand weather and working our way through it is going to have a substantial safety benefit, and it is something we depend on NASA for.

If we are truly going to expand aviation capacity to meet the growing demand for air transportation and reap the benefits from that, we have to recognize that aviation must be more and more environmentally friendly. Administrator Goldin touched on a couple of key programs in that respect, including the quiet aircraft technology program and the ultraefficient engine program. These again are all programs that NASA is working on in terms of aviation, which benefit not just the aviation community, but our Nation as a whole. They should be a priority for us. We should invest in these.

I think when you look at the President's budget for NASA, and you look at what NASA is doing, you have to walk away concluding everything in there is very important. It is absolutely essential, and, in fact, we should be doing a lot more than just what we are doing. I think we should be pursuing supersonic transport technologies. It is something that we need to look at. I think there are things that we could be doing to look at wake vortices, understanding better the wake that follows aircraft so perhaps we can find ways to reduce separation standards and increase capacity.

But I will tell you, Mr. Chairman, that the aviation community is interested in working with NASA, and going beyond just working with NASA, but doing what Administrator Goldin said, and that is combining the resources of NASA with the DOT, with the FAA, and with the aviation community, so we can make sure that the products lead to development and lead to certification and lead to procedures that go with it, so that we can all recognize and receive the benefits of increased capacity and increased safety, and increased environmental friendliness.

Thank you very much.

[The prepared statement of Mr. Bolen follows:]

PREPARED STATEMENT OF EDWARD M. BOLEN, PRESIDENT, GENERAL AVIATION MANUFACTURERS ASSOCIATION

Mr. Chairman, Senator Breaux, and Members of the Subcommittee, my name is Edward M. Bolen and I am President of the General Aviation Manufacturers Association (GAMA). GAMA represents approximately 50 manufacturers of general aviation aircraft, engine, avionics and component parts located throughout the United States.

GENERAL AVIATION

As everyone on this Subcommittee well knows, general aviation is defined as all aviation other than commercial and military aviation. It is the backbone of our air transportation system and is the primary training ground for the commercial airline industry. It is also an industry that contributes positively to our nation's economy.

General aviation aircraft range from small, single-engine planes to mid-size turboprops to the larger turbofans capable of flying non-stop from New York to Tokyo. These planes are used for business purposes and recreation, as well as everything from emergency medical evacuations to border patrols and fire fighting. They are also used by individuals, companies, state governments, universities and other interests to quickly and efficiently reach the more than 5000 small and rural communities in the United States that are not served by commercial airlines.

GROWTH IN GENERAL AVIATION MANUFACTURING

Since passage of the General Aviation Revitalization Act (GARA) in 1994, general aviation manufacturers have posted 6 straight years of increased billings and increased shipments. That is quite an accomplishment.

Product liability reform has allowed general aviation manufacturers to allocate valuable resources toward research and development of new, exciting, safe and environmentally friendly products to the market. In addition to private research being conducted by many GAMA member companies, we are working in conjunction with NASA on their research programs for general aviation.

NASA RESEARCH IS CRITICAL TO U.S.

NASA research plays a critical role in the future of the U.S. aeronautics industry. The U.S. has maintained its world leadership in aeronautics because we have long understood that basic scientific and technical research is an appropriate government function.

It is especially important to understand now that the Europeans have published a public document, "A Vision for 2020", stating their goal to wrest the leadership in aeronautics research from the U.S. They have proposed a broad range of research and development programs and educational efforts recommending $93 billion be invested in the next 20 years.

At GAMA, we believe NASA research is critical to our nation's competitiveness. This type of research is long term, very high risk, and would not normally be justified by any commercial company. It is undertaken well before commercial products are developed, at the "pre-competitive" level. In fact, experience has shown that a company may still need to invest hundreds of millions of dollars to take a NASA-developed technology and bring it to the marketplace.

One example that may be helpful to you in understanding the competitiveness issue is in the area of high-speed civil transport. Supersonic speed is largely viewed as the next frontier for intercontinental business jets. However, due to budget shortfalls, NASA is no longer funding this program. Meanwhile, France, Russia and Japan are each pursuing a supersonic business jet program.

NASA aeronautics research is an investment in the future, and the primary beneficiary is the traveling public, who benefits from a safer, more efficient, environmental and economical air transportation system. But as the nation's air transportation system continues to grow, so do environmental concerns.

This year's NASA budget funds two programs worth mentioning here. First is the Ultra Efficient Engine Technology program. It is focused on researching advanced technologies to reduce emissions. Second is the Quiet Aircraft Technology program. This important program seeks to find solutions for reduced jet noise. Both should continue to receive Congressional support. NASA research will make revolutionary changes in both areas possible.

Other beneficiaries of NASA research are the employees of aerospace companies holding the high-paying jobs needed to produce these new products. And as the result of NASA's research eventually enters into the public domain, manufacturers based outside the U.S. also reap the benefits of NASA's investment.

Given the benefits NASA's research provides to the nation's economy, we strongly support the continued allocation of general taxpayer dollars to the NASA Aeronautics budget.

BENEFITS OF NASA RESEARCH

In my testimony today I thought I would talk about the benefits we have already received from NASA research programs, as well as some of the technologies that are being developed as a result of NASA's focus on general aviation.

The Advanced General Aviation Transport Experiment (AGATE) was a NASA cost sharing partnership with industry to create the technological basis for revitalization of the U.S. general aviation industry. The goal of the program was to develop affordable new technology as well as the industry standards and certification methods for airframe, cockpit and flight training systems for next generation single pilot, 4–6 place, near all-weather light airplanes.

AGATE focused attention on moving technology that had been available only to commercial air carriers to general aviation aircraft. NASA and industry worked closely with FAA to bring electronic display regulations into line with current technology. As a result, we will soon see new avionics in general aviation aircraft that are cheaper, more reliable and provide better information to the pilot, advancing the safety of our industry.

Another success of AGATE has been the streamlined certification standards for composite materials. Composites are lighter weight than steel and provide unique benefits for fuel efficiency.

NASA's General Aviation Propulsion (GAP) program aimed to develop revolutionary new propulsion systems for general aviation. Historically, it is new engines that have brought about the greatest changes in aircraft design and performance. At the entry level of general aviation, some very exciting new engines are on the verge of reaching the market.

NEW ENGINE TECHNOLOGIES

One of the most exciting engine developments is from Williams International, the new FJX-2 turbofan engine. Planned to weigh one hundred pounds or less, it will produce at least 700 pounds of thrust. With an extremely economical price, the Williams engine could be a feasible choice for even the smallest airplane.

Teledyne Continental Motors and Textron Lycoming are developing a new generation of internal combustion engines, with distinct advantages over current piston-powered engine designs. First, the number of moving parts is greatly reduced, simplifying both engine production and maintenance. This also reduces weight and engine noise while improving reliability. Equally as important, these engines will be able to use jet fuel. The result will be an engine with better performance and high reliability, but much lower cost.

Teledyne Continental Motors' engine is due in part to the Internal Combustion Engine Element of NASA's GAP program. The goal of this element of the GAP program was to reduce engine prices by one half while substantially improving reliability, maintenance, ease of use, and passenger comfort.

In addition to new engines, these manufacturers are also developing new electronic engine controls that will not only add to the performance of new engine designs, but could greatly improve performance of the existing piston-engine fleet. Single-lever power controls will simplify engine operations and reduce the potential for operator error. Teledyne Continental Motors is developing a new Full Authority Digital Engine Control system, or FADEC, which incorporates an innovative microprocessor architecture designed to provide a high degree of redundancy. This product has been developed as a result of AGATE.

Another engine control product, developed outside of the AGATE Consortium, is Lycoming and Unison Industries' Electronic Propulsion Integrated Control system, or EPiC program. EPiC is a completely integrated digital propulsion system for new certified piston-powered aircraft that will provide exact engine propulsion management.

Likely to complement the new engines are new propeller designs by companies like Hartzell. These new propellers will not only improve efficiency, but they will also make smaller airplanes even quieter than they are today.

But what benefits to our aviation system will these new engines bring? The future general aviation engines will have dramatically reduced emissions and noise and will be extremely fuel efficient at a low cost. Their reliance on jet fuel is a major breakthrough given the environmental concerns over continued use of leaded aviation gasoline in today's general aviation piston engines. Last, although certainly not least is safety. The new engine technologies will bring a greater measure of safety to flight through enhanced reliability and easier maintenance due in part to the fewer moving parts found in these engines.

NEW AVIONICS TECHNOLOGIES

Building on the FAA's National Airspace System (NAS) modernization plan and the Global Positioning System (GPS), general aviation manufacturers have been busy developing new products that will dramatically increase safety and efficiency of the current aviation system.

NASA also makes significant contributions to advanced air traffic control procedures and equipment. We are pleased that the FAA and NASA have worked closely to coordinate their ATC research activities, and avoid duplication of efforts and leverage resources as much as possible. This NASA-FAA partnership is working, and should continue.

Once the Wide Area Augmentation System (WAAS) is certified by FAA, a new generation of GPS/WAAS receivers from companies like GARMIN, Honeywell and UPS Aviation Technologies will be brought to market. These receivers will offer fast and easy access to basic navigation functions, and there will be standard function labels and abbreviations regardless of equipment manufacturer.

As our industry continues to benefit from laptop computer-display research, we can expect cockpit displays in smaller aircraft to become even more sophisticated and less expensive than they are today. As a result, advanced multi-function displays (MFD) similar to the ones currently manufactured by Avidyne, Rockwell Collins, Honeywell and others will be ubiquitous.

When coupled with a GPS/WAAS receiver, these new multi-function displays will not only depict a moving map, but also nearby terrain, engine operating parameters and other important information such as actual fuel burned versus the amount planned. The basic attitude and heading displays of the aircraft will be depicted in such a way that IFR flight can be easily accomplished. These technologies are being developed due in part to NASA's AGATE Consortium.

BFGoodrich, Honeywell, and Universal Avionics have announced Terrain Awareness and Warning Systems, or TAWS, for small GA aircraft. Controlled Flight Into Terrain (CFIT) is a leading cause of general aviation accidents. With situational awareness technology in the cockpit, pilots will have information at their fingertips about the terrain over which they are flying.

Also to help address CFIT accidents, NASA and the FAA are cooperating on a 5-year program to develop synthetic vision systems. Synthetic vision combines GPS with a precise terrain database to provide the pilot with the equivalent of daytime, clear weather view of the surrounding terrain even if the pilot is actually flying in nighttime, bad weather conditions.

Companies like Avidyne, GARMIN, Rockwell Collins and Honeywell are working on products that will allow near real-time weather and weather forecasts to be displayed in the cockpit via ground-to-air or satellite datalink. Weather is the leading cause of general aviation accidents. Datalink will provide timely weather information in the cockpit so pilots can make better decisions about whether or not to proceed to their destination. NASA's Aviation Weather Information System (AWIN) is focused in these areas.

The FAA is field testing in the Ohio Valley and Alaska ADS-B products by UPS Aviation Technologies that will allow traffic information to be automatically displayed via air-to-air datalink from nearby aircraft. This new technology allows pilots in the cockpit and air traffic controllers on the ground to see air traffic with more precision than radar and other tools allow. By relying on the GPS signal, pilots will see precisely where aircraft near them are and will know their intentions. Importantly, ADS-B could permit the airspace to be more efficiently utilized, increasing capacity and reducing delays in the system.

Looking at all of these exciting new technologies, it is easy for me to get very enthusiastic about the future of general aviation, and I haven't even mentioned some of our great new training products, autopilots, or some of the advances being made by some of GAMA's component manufacturers.

These new technologies will yield both improved margins of safety and increased operating efficiencies. The margin of safety will be dramatically improved when every paved and lighted airport in our nation can offer an instrument approach with vertical guidance. And when aircraft can fly on nearly any route they choose, and still be assured they remain well-clear of conflicting traffic or terrain, we will have achieved a new era of efficiency and safety for both aircraft operators and passengers alike. Finally, the safety benefits of timely weather information provided to pilots in the cockpit through datalink cannot be understated.

Building on all of these emerging technologies, GAMA believes there is a significant role for general aviation in our nation's future air transportation system.

GENERAL AVIATION'S ROLE IN THE NATION'S FUTURE AIR TRANSPORTATION SYSTEM

As this committee well knows, general aviation provides critical access today to communities not served by air carriers. It connects small communities and businesses to the economic mainstream. Without access to airports, local officials would not be able to attract new business and economic investment in their communities.

However, if general aviation can be more efficiently utilized, and we believe it can, then we can help to solve the capacity problems currently facing the air transportation system. With hub airports approaching gridlock at an ever-increasing pace, capacity of the current system is a legitimate concern. Improvements in the technology of general aviation aircraft, avionics and engines will make general aviation for a growing number of people an even safer, more reliable and affordable alternative to today's commercial air transportation system.

This is also the vision of NASA's Small Aircraft Transportation System (SATS). The goal of SATS is to develop an innovative solution to air transportation delays. By dramatically increasing the reliability and safety of general aviation aircraft, air travel can be transformed.

SATS is focused on achieving these goals through advancements in aviation technologies. These technologies include advanced flight controls and innovative avionics for near-all-weather access to any airport. In addition to aircraft technologies, NASA is focusing on investment in airport infrastructure. The program envisions the safe use of general aviation airports without additional control towers, radar or additional runway protection zones. Enhancing general aviation access to the over 5,000 airports across the nation greatly increases the capacity of our air transportation system. Rural counties and other areas will economically benefit from the increased access and capacity the SATS-developed technologies will bring.

Another major focus of the SATS program has been to encourage smarter manufacturing techniques by drawing on automotive manufacturers' expertise. NASA has shown today's manufacturers of general aviation aircraft that mass production is possible if we incorporate some of the automakers' best practices into general aviation manufacturing. And basic economics tells us that increased production will drive down costs, making these more efficient, safer products more affordable for general aviation pilots.

SATS also has a goal to reduce pilot training and proficiency requirements through increased use of safety-oriented technologies. When these technologies are deployed, access to personal aircraft travel will increase dramatically.

I know that there are those who may question whether my vision for the future of general aviation is realistic. They may argue that the challenges to growing our industry are too great and our resources are too few.

But I would remind those people that, for nearly 100 years, those of us in aviation have delighted in proving naysayers wrong. Like the Wright brothers themselves, we know that with determination and innovation, nothing is impossible.

CONCLUSION

Thank you for the opportunity to testify today. I would be happy to answer any questions you might have.

Senator ALLEN. Thank you, Mr. Bolen.

Mr. Deel, you are next on our list.

STATEMENT OF DENNIS DEEL, PRESIDENT, LOCKHEED MARTIN SPACE SYSTEMS COMPANY, MICHOUD OPERATIONS

Mr. DEEL. Mr. Chairman and Senator Breaux, I am deeply grateful for your invitation to appear before your Subcommittee hearing today, and I think from the earlier dialog, it is obvious that the subject of today's hearing is certainly important and timely. As your Ranking Member said earlier, our company is located at NASA's Michoud Assembly Facility in New Orleans, and our primary product there is the external fuel tank for the Space Shuttle. Today it is my privilege to speak with you on behalf of the Lockheed Martin Corporation about some of the important contributions that NASA makes to our national goals, specifically in the areas of aeronautics and space research.

Let me highlight just a few examples of the benefits of the long-standing collaborative aeronautics research efforts between Lockheed Martin and NASA, specifically some of those targeted at NASA's Langley Research Center. The conception, development and deployment of the F-16 fighter, currently a mainstay in both the United States and the allied air forces, has been greatly enhanced by a close relationship between Lockheed Martin and the NASA Langley Research Center. The next generation air dominance weapons systems, the F-22 Raptor, will ensure that the United States can secure and maintain air dominance, a prerequisite for a successful military operation. We used the results of Langley's research and development to achieve enhanced maneuverability and drag reduction on the F-22.

In the big-airplane military inventory, NASA's contributions are equally impressive. For our military's largest transport plane, the C–5, unique wind tunnel assets at Langley were used to predict air dynamic interference between the wing and engine cells and pylons, and to evaluate effects such as wake turbulence and landing power and active load alleviation reduction. The world's newest tactical transport, the C130-J, uses state-of-the-art liquid crystal flat panel flat displays, technology also developed in concert with NASA.

But over the last several years, the lines of demarcation between aeronautics and space research have become blurred. The design methods, the modeling techniques and the structures and materials developments are often equally applicable in both environments. My specific division of Lockheed Martin is responsible, as I said, for the design and production of the external tank for the Shuttle. I would like to just relate some specific examples where Langley and my company have successfully worked together in providing specific developments that were then made available to this Nation's launch vehicle industry and also successfully incorporated into the Space Shuttle program.

NASA Langley played a key role in the development of the high-strength, lightweight aluminum alloy called aluminum lithium 2195. This material, initially invented by Lockheed Martin, is currently flying on our Space Shuttle External Tank. In the late 1980s and early 1990s, Langley and Lockheed Martin worked together to further develop and to commercialize the material, and Langley successfully proved the feasibility of using this material for large-scale, expendable launch vehicle cryogenic tanks, to improve safety margins and payload delivery performance.

In 1994, NASA's Marshall Space Flight Center decided to develop a redesigned External Tank made of this lightweight aluminum alloy. That has been executed. It provides the Space Shuttle with 7,500 pounds of additional payload capability. It has enabled the Shuttle to have the performance to perform the mission that it's achieving today, launching the components and building the international space station. That was a very cost-effective change. That saved NASA on the order of $800 million of savings from other programs that they would not have to use.

Today Langley and Lockheed Martin are continuing to work together to test applications of state-of-the-art friction stir welding technology with applicability to the tank and military and commercial aircraft components. Langley has provided hardware and development testing and demonstrations to support the MSFC decision to implement that technology as a Space Shuttle upgrade project.

So in summary, Lockheed Martin is engaged with NASA on several levels that are of national interest, in the development of the world's best military defense capabilities, to ensure our Nation's future in space. It has been a team effort. We recognize that Langley Research Center is an invaluable partner for Lockheed Martin and the rest of the aerospace industry, as well. Their unique test facilities, their proven technical expertise, their development management capabilities, are national assets critical to the continued advancement of aeronautics and the successful exploitation of space.

We rely on NASA to push the envelope, as Administrator Goldin said, in developing the technologies. As a Nation, we need a strong commitment to the continuation of this important work. I am encouraged to hear that NASA is requesting additional budget. I certainly share their concerns that as we have continued to do more with less over the last 9 years, we have increased the pressure on our key capital resource, our people, especially our young people, every year doing more with less, and we need to turn the trend around. It is key that we support NASA's investment in technology.

Chairman Allen, I would like to thank you again for holding this Subcommittee hearing, and I appreciate your invitation to speak, and that concludes my remarks.

[The prepared statement of Mr. Deel follows:]

PREPARED STATEMENT OF DENNIS DEEL, PRESIDENT, LOCKHEED MARTIN SPACE SYSTEMS COMPANY, MICHOUD OPERATIONS

Mr. Chairman, distinguished Members of the Senate Science, Technology, and Space Sub-Committee, my name is Dennis Deel, President of Lockheed Martin Space Systems Company, Michoud Operations. Chairman Allen, I am deeply grateful for your kind invitation to appear before your Subcommittee's inaugural hearing. The subject of today's hearing is certainly important and timely. Our facility is located in the state of Louisiana, home of Senator John Breaux, the Ranking Member of your Subcommittee, at NASA's Michoud Assembly Facility in New Orleans. It is my privilege and honor to speak with you today on behalf of the Lockheed Martin Corporation about some of the important contributions that NASA makes to our national goals, specifically in the areas of aeronautics and space research. I will first discuss Langley's importance to our Nation's aeronautics industry and then discuss their contributions to the space industry, an industry in which I am personally involved.

An entering condition for our Nation's economic stability and prosperity is national security—and providing the tools and means for guaranteeing that security is our business at Lockheed Martin. The fundamentals of aeronautics obviously apply to all things that fly—be they airliners or air dominance fighter planes. Likewise, the scientists, researchers, research facilities, world-class laboratories and wind tunnels resident at the NASA Langley Research Center provide the means for developing, testing and validating innovative technological advancements on all classes of aero vehicles, whether they are commercial or military.

Industry by the very nature of business is focused on the nearer term. NASA on the other hand, as a government research agency, is like an incubator, helping sustain support for the cutting edge research so critical to our Nation's security and prosperity. Let me highlight just a few examples of the synergistic benefits of the longstanding collaborative aeronautics research efforts that are underway between Lockheed Martin and NASA, specifically those preformed, or being performed, at NASA's Langley Research Center.

The conception, development, and deployment of the F-16, currently a mainstay in both the U.S. and allied air forces, have been greatly enhanced by a close relationship between Lockheed Martin Aeronautics and the NASA Langley Research Center. NASA researchers and facilities helped solve numerous challenges over the years including spin recovery, high angle-of-attack stability, flutter clearance and deep stall recovery. Additionally, the F-16 deployed "fly-by-wire" technology and the side stick controller—both key technologies that were developed at Langley. In a cooperative program, we developed supersonic wing design methods and test processes used in the F-16XL supersonic cruise prototype. This research has greatly enhanced the development of the next generation air dominance weapons system—the F-22 Raptor.

The F-22 Raptor will help ensure that the United States can secure and maintain air dominance—a prerequisite for successful military operations that we have enjoyed since Desert Storm. We used the results of Langley's research and development of thrust-vectoring non-axisymmetric nozzles and after-body integration to achieve enhanced maneuverability and drag reduction on the F-22. Additionally, Langley's support of our F-22 high angle-of-attack analysis led to outstanding agility and resistance to spin, both of which have been successfully demonstrated in the flight test program.

In the "big airplane" military inventory, NASA contributions are equally impressive. For our military's largest transport plane, the C-5, unique wind tunnel assets at Langley were used to predict aerodynamic interference between the wing and engine nacelles and pylons. In addition, C-5 wake turbulence, landing power, and active wing load alleviation effects were explored using Langley facilities. Additionally, an enhanced tail structure was recommended as a result of Langley parametric tests.

Finally, we've used Langley developed aerodynamic computational codes in configuration development for the various models of the venerable C-130 Hercules since the 1950s. Under Langley sponsorship, we developed an advanced boron reinforced metal center wing box for the airplane and tested a composite center wing box. This development provided application expertise that has been crucial in F-22 manufacture. The world's newest tactical transport, the C-130J, uses state-of-the-art liquid crystal flat-panel flight displays—technology also developed in concert with NASA.

Still in the inventory and for years the "Backbone on the Airlift Fleet", the C-141 Starlifter also relied on NASA developed aeronautics technology. We learned about "T-tail transonic flutter" in a Langley wind tunnel. Together, we discovered, investigated and solved basic aerodynamic anomalies including elevator-induced flutter and aileron reversal.

The NASA-Lockheed Martin partnership has equally enhanced the quality of systems operated today by the U.S. Navy and allied countries. The P-3 Orion, a variant of which recently dominated the international news, benefited from tests in the Langley transonic dynamics tunnel. Tests identified catastrophic propeller-whirl flutter and resulted in engine mount modifications. Additionally, the S-3 Vikings flutter clearance and spin recovery characteristics were evaluated in Langley based tests.

Longer term, we rely on NASA to "push the envelope" in technology development. For the past several years, NASA's Advanced Aircraft Program has broken new ground in providing key enablers that have allowed us to produce superior and survivable aircraft. As a nation, we need a strong commitment to continuation of this important work.

Over the past several years, the lines of demarcation between aeronautics and space research have become blurred. The design methods, the modeling techniques, and the structures and materials discovery are often equally applicable in both environments. My specific division of Lockheed Martin is responsible for design and production of the External Tank for the Space Shuttle, this nation's first reusable launch vehicle. As mentioned earlier, this activity is performed on the NASA Michoud Assembly Facility in New Orleans. We have also been heavily involved in the X-33/Reusable Launch Vehicle (RLV) programs. On the X-33 program, for example, we are responsible for design and production of the metal cryogenic propellant tanks and the main propulsion system, as well as ground demonstrations of state-of-the-art composite liquid oxygen tank technology.

I would like to relate some specific success stories where Langley and my company have successfully worked together in providing significant technology developments that were then made available to this nation's expendable launch vehicles and successfully incorporated into the Space Shuttle and X-33 programs.

As the original NASA Manned Space Center, Langley Research Center has, starting with the Mercury program, decades of successful experience supporting the development of this nation's human space flight program. Industry recognizes that Langley continues to have a key role in supporting NASA's Space Flight and Space Transportation activities. Langley is NASA's Center of Excellence for materials and structures research. On NASA's Space Launch Initiative and Advanced Space Transportation programs, Langley is responsible for managing the development of all airframe technologies ranging from cryogenic tanks to wings, flight surfaces, and thermal protection systems. We look forward to working with Langley on these two exciting programs which are aimed at providing safer, more reliable and less expensive launch systems to help this country fully realize the commercial potential of space.

NASA Langley played a key role in the initial development of a high strength, lightweight aluminum alloy called aluminum lithium 2195. This material, initially invented by Lockheed Martin, is currently flying on the Space Shuttle External Tank. In the late 1980s and early 1990s, Langley and Lockheed Martin worked together, initially on company funded basic research and then later on the joint NASA /DOD Advanced Launch System (ALS) program, to further develop and commercialize the material. Langley's efforts included electron microscopy to characterize the elemental structure of the new alloy and refine its manufacturing processes. During the ALS program, Langley personnel provided technical oversight for the alloy chemistry optimization, manufacturing process development, welding process development and large-scale component demonstrations. Langley successfully proved the feasibility of using this material for large-scale cryogenic expendable launch vehicle tanks to improve their safety margins and payload delivery performance. Langley also successfully managed the development of near net shape technology that proved the feasibility of economically forming this material into its final part form minimizing costly machining and chemical etching normally required in building the part.

Building on the success demonstrated on the ALS program, in 1994 the NASA Marshall Space Flight Center decided to develop a redesigned External Tank made of the aluminum-lithium material to provide a 7,500-pound payload increase required for the Space Shuttle to successfully deliver key components to the International Space Station. The economic significance of this important development was an approximate $800 million cost savings to NASA by avoiding the completion of other more costly shuttle performance enhancement options. NASA Marshall Space Flight Center and Lockheed Martin could not have been successful in developing the aluminum lithium External Tank within cost and on schedule without the direct contributions of key Langley personnel. Langley's critical Super Lightweight External Tank development roles included design evaluation support and daily technical assistance in areas of alloy chemistry, fracture mechanics, thermal mechanical properties and hardware certification. These efforts helped the Marshall Space Flight Center transition aluminum lithium 2195 from a development material into full-scale commercial production.

Today Langley and Lockheed Martin are continuing to work together to test representative applications of state-of-the-art Friction Stir Welding technology on both External Tank and military and commercial aircraft components. Friction Stir Welding is being incorporated by Marshall Space Flight Center on the External Tank program as a part of the NASA's Shuttle Upgrades; a program which is aimed at increasing safety and improving reliability of key Space Shuttle systems. Langley provided demonstration hardware utilized for development testing and proof of concept demonstrations leading up to the Marshall Space Flight Center decision to implement this important Shuttle Upgrade project.

In 1995, we became involved in the X-33/Reusable Launch Vehicle program. One of the key challenges was to develop lightweight structures and tanks that were both robust enough for multiple missions but light enough to meet Single-Stage-to-Orbit mass requirements. One technology needed to help meet these two requirements was a structural health monitoring sensor system. This system provides real time feedback and analysis of the structural loads experienced during a mission and would be used to help validate that the vehicle airframe is safe to fly again which assists rapid turnaround for the next mission. We turned to LaRC to help develop a sensor system for the X-33 program to satisfy this requirement. Langley engineers successfully qualified and provided the structural sensor system to the X-33 program and the system has been installed on the X-33 vehicle.

Langley also provided significant support on the X-33 program in the testing and evaluation of combined cycle thermal and mechanical loading of reusable cryogenic insulation materials and developed a unique test capability that incorporated temperature extremes at mission conditions. Langley has since successfully developed and commercialized a cryogenic insulation.

Finally, we have also received significant design review, trade study and composite panel testing support from Langley to support our composite liquid oxygen tank development activities; activities we have performed as part of the X-33 ground demonstration program and the X-34 composite liquid oxygen development program.

In summary, Lockheed Martin is engaged with NASA on several levels that are all of national interest. From the development of absolutely the world's best military defense capabilities to our assuring our Nation's future in space, it is team effort. We recognize Langley Research Center as invaluable partner for Lockheed Martin and the rest of the aerospace industry. Their unique test facilities, proven technical expertise and development management capabilities are national assets critical to the continued advancement of aeronautics and the successful exploitation of space.

Chairman Allen, I want to thank you again for holding this important hearing today and for asking me to participate in it. I am ready to respond to your questions.

Senator ALLEN. Thank you. We would now like to hear from Mr. Roy V. Harris, who is Chief Technical Advisor, NASA Aeronautics Support Team.

STATEMENT OF ROY V. HARRIS, JR., CHIEF TECHNICAL ADVISOR, NASA AERONAUTICS SUPPORT TEAM, HAMPTON, VA

Mr. HARRIS. Thank you, Mr. Chairman. The NASA Aeronautics Support Team is delighted to have this opportunity to present its views on NASA's aeronautics program. We are concerned that NASA's aeronautics program has been reduced by about one-third in recent years, and that the Bush fiscal year 2002 budget proposes additional reductions that could result in a funding level of about one-half the 1998 aeronautics program, or, put another way, less than 4 percent of NASA's 2002 overall budget.

We are also aware that NASA is developing, as Administrator Goldin alluded to in his remarks, an aeronautics vision for the 21st century, which will be released by September of this year. We applaud this effort and believe that it is a necessary step in revitalizing the NASA aeronautics program. However, we also believe that the continued reductions in funding for aeronautics research are inconsistent with any realistic plan to implement the vision. As others have mentioned, 25 years ago, the U.S. had 90 percent of the world market for commercial aircraft sales. Ten years ago, the U.S. share had dropped to about 70 percent. Today, our market share is about 50 percent. That sounds like a going-out-of-business curve to me.

Still, aircraft sales are a large positive contributor to the U.S. trade balance, about $41 billion in 1998 and $33 billion in 1999. It seems incomprehensible to us that while our European competition is calling for increased government funding for aeronautics research, in order to gain leadership over the United States and potentially eliminate the only U.S. industry that produces a large positive balance of trade, that our government is continuing to reduce its support for this investment in our future. Perhaps even more important, the U.S. transportation system, as others have pointed out, is headed toward a major crisis. The problems we have been experiencing with increasing flight delays and near-misses are just the tip of the iceberg.

A safe, effective and efficient national transportation system, with ample capacity to keep up with increased demand, is essential for the U.S. economy to continue to grow. It is also absolutely essential for the continued growth of e-commerce, since products bought over the Internet must be delivered by the transportation system. Throughout their history, NASA and its predecessor, the NACA, invested heavily in world-class national test facilities, such as wind tunnels, structural test facilities, simulators and flight test facilities, and have developed a technical staff of scientists, engineers and technicians who are second to none in the world.

Unfortunately, funding for NASA's aeronautics program has been reduced to the point that we are losing our depth of expertise and the national test facilities are being starved for adequate maintenance and desperately needed upgrades. We agree with the 1999 report by the Committee on Strategic Assessment of U.S. Aeronautics, by the National Research Council, which I think you quoted in your introductory remarks, and, I quote,

> "Continued reductions in funding for aeronautics R&D may have irreversible consequences; once the leadership position of the United States in aeronautics

is lost, it will be exceedingly difficult to regain, because of the difficulty in reassembling the infrastructure, people and investment capital."

The NASA aeronautics budget was reduced by about one-third in fiscal 1999 and 2000, almost all work on developing the technologies for a future U.S. supersonic airliner were terminated. In addition, the advanced subsonic technology program was canceled. The Bush fiscal 2002 budget proposes two additional major reductions, the elimination of all NASA rotorcraft research, and as best we can understand it, essentially all NASA-funded military aviation research. This effectively severs the long-standing, cost-effective partnership between NASA and the DOD, on which the U.S. depends for military superiority.

We understand that the budget pressures faced by NASA and which were described by Mr. Goldin, are very severe, and we understand the need for the development of new technologies for more efficient space launch capability. However, we do not believe that the Nation can afford to sacrifice NASA's traditional aeronautics research in order to satisfy space program demands. We believe that NASA's vision for the 21st century will present an exciting picture for the future. However, we do not agree that the vision can be realized by reinvesting the already subcritical aeronautics budget into a few potentially revolutionary new technologies.

NASA must maintain a complete aeronautics program, encompassing all relevant technical disciplines and vehicle classes. We believe that this can be accomplished only by a doubling of the aeronautics portion of NASA's budget.

In conclusion, we believe that NASA's overall budget does need to be increased in order to provide the funds necessary for a world-class aeronautics research program. Our national economic well-being depends on it. Our national defense depends on it, and it will impact the quality of life of all Americans.

Thank you.

[The prepared statement of Mr. Harris follows:]

PREPARED STATEMENT OF ROY V. HARRIS, JR., CHIEF TECHNICAL ADVISOR, NASA AERONAUTICS SUPPORT GROUP

Mr. Chairman and distinguished Members of the Subcommittee on Science, Technology and Space, the NASA Aeronautics Support Team (NAST) is delighted to have this opportunity to present its views on NASA's aeronautics program. NAST is a private, nonprofit organization advocating for "the first A" in NASA—aeronautics research—which we believe is essential for a safe and effective U.S. air transportation system, superior U.S. military aviation technology, and an internationally competitive U.S. civil aircraft industry.

We are concerned that NASA's aeronautics program has been reduced by about one-third in recent years (See attached chart 1.), and that the Bush FY02 budget proposes additional reductions that could result in funding at a level of about one-half the FY 1998 aeronautics program (or, less than 4% of NASA's 2002 overall budget). It should be noted that this estimate is based on our own analysis of the of the FY02 budget proposal. NASA no longer has a line item in its budget for aeronautics, making it very difficult for Congress and the public to determine how much (or how little) is being spent in this very important area. (See attached charts 2 through 5.)

We are also aware that NASA is developing an aggressive "Aeronautics Vision for the 21st Century" to be released by September 2001. We applaud this effort and believe that it is a necessary step in revitalizing NASA's aeronautics program. However, we also believe that the continued reductions in funding for aeronautics research are inconsistent with any realistic plan to implement the vision.

We are encouraged by passage of the amendment offered by VA/HUD Appropriations Subcommittee Chairman Christopher Bond (R-MO) and Ranking Democrat

Barbara Mikulski (D-MD) to increase funding for Function 250 by $1.44 billion in FY2002. It is our understanding that $518 million of that amount is designated for NASA. We hope that a significant portion of these funds will be allocated for aeronautics research.

U.S. AVIATION IN CRISIS

Twenty-five years ago, the U.S. had over 90% of the world market for commercial aircraft sales. Ten years ago the U.S. share of that market had dropped to about 70%. Today our market share is about 50%, and some project that it will reach as low as 30% in the near future. Still, aircraft sales are a large positive contributor to the U.S. trade balance, 41 billion dollars in 1998 and $33 billion in 1999. Aircraft sales have a very high leverage on balance of trade. For example, one Boeing 747 sold overseas cancels out ten thousand foreign automobiles sold in this country. In addition, civil aviation directly employs about 800,000 highly paid workers, and another 2 million support workers. We cannot afford to give this lucrative market away to our foreign competitors.

Realizing the societal benefits of this huge potential market in which they are gaining the competitive advantage, the European Commission has laid out an aggressive plan: In a report entitled "European Aeronautics: A Vision for 2020" they state their two ultimate goals—global aeronautics leadership in Europe, and a world class European air transportation system that will be copied by the rest of the world. It recognizes that "aeronautics is a particularly high-tech business working on long lead times and requiring huge capital sums". The report recommends the creation of an "Advisory Council for Aeronautics Research in Europe" and states that it "must be facilitated by an increase in public funding", and that "total funding required from all public and private sources over the next 20 years could go beyond 100 billion Euros" (about $95 billion).

It seems incomprehensible to us that while our European competition is calling for increased government funding for aeronautics research in order to gain leadership over the U.S. and eliminate the only U.S. industry that produces a large positive balance of trade, that our government is continuing to reduce its support for this investment in our future.

Perhaps even more important, the U.S. transportation system is headed toward a major crisis. The problems that we have been experiencing with increasing flight delays and near misses are just the tip of the iceberg. Air traffic will nearly double in the next decade and will triple in 20 years. The U.S. transportation system will completely choke in about 8 to 10 years if solutions are not found. The FAA and the airlines are focused on finding solutions to the very significant problems that exist today, while NASA needs to be doing more to develop solutions to the vastly more difficult problems looming in the future.

As air travel triples in the next two decades, it will also be necessary to make significant improvements in aviation safety and environmental impact. Despite an alarming increase in aviation accidents in recent years, the aviation accident rate is still very low and air travel remains the safest method for long distance travel. Nevertheless, even if we can maintain the current low accident rate and as air traffic significantly increases in the coming decades, we will see a dramatic increase in aviation accidents if the already low accident rate isn't significantly reduced. Some have projected that a failure to reduce the accident rate will result in a major accident every week within the next two decades. In addition, noise and pollution problems at our major airports will become significantly worse as air travel increases.

A safe, effective, and efficient national transportation system with ample capacity to match the increasing demand is essential for the U.S. economy to continue to grow. It is necessary in order to bring goods to market, parts and supplies to our factories, and people to all points of the globe. It is also absolutely essential for the continued growth of e-commerce, since products bought over the internet must be delivered via the transportation system. The national airway system is the only component of our transportation system (air, rail, highway, and sea) that has any hope of expanding to meet the needs of a growing U.S. economy. The coming transportation crisis could bring an end to U.S. economic expansion and will be a quality of life issue for all Americans.

NASA also has an important role to play in military aviation technology. The first NASA (then NACA) aeronautical laboratory at Hampton, VA and the first U.S. military aeronautical laboratory at Dayton, OH were authorized by the same act of Congress in 1915 (a reaction to the realization, after World War I, that Europe was ahead of the U.S. in aviation technology). Both facilities initially focused on military aviation technology. Thus, a partnership evolved in which NACA performed basic research and investigated long-term potential applications and DOD focused on development testing and near-term applications.

Numerous aeronautics "breakthroughs" have resulted from this very cost-effective partnership. Some recent examples include shaping for stealth; multi-axis thrust vectoring exhaust nozzles integrated with aircraft flight-control systems; fly-by-wire flight control technologies; high-strength, high-stiffness fiber composite structures; and tilt-wing rotorcraft technology. Many of these advances are now finding widespread use in both military and civil aircraft. We believe that the U.S. has produced second-to-none U.S. military aircraft for 86 years as a direct result of this partnership. Now, for the first time, NASA's participation in the partnership seems to be threatened.

In a recent letter to the Secretary of Defense, the NASA Administrator stated that: "This program [the NASA Advanced Aircraft Program (AAP)] has been a key element of our partnership with the Air Force for many years. Increasing budget pressures over the last several years have not abated and have led us to consider terminating the AAP." It is our understanding that the AAP is zero-funded in FY02.

Throughout their history, NACA and NASA have invested heavily in world class, national test facilities (such as wind tunnels, structural test facilities, simulators, and flight test facilities) and have developed a technical staff of scientists, engineers, and technicians who were second-to-none in the world. NASA has become the national 911 for both civil and military aviation problems, and is the only federal agency with the in-house expertise, experimental test facilities, computational tools, and far-term research focus required to provide long-term solutions to future civil and military aviation problems. Unfortunately, funding for NASA's aeronautics program has been reduced in recent years to the point that we are losing our depth of expertise and the national test facilities are being starved for adequate maintenance and needed upgrades.

We agree with the 1999 report by the Committee on Strategic Assessment of U.S. Aeronautics of the National Research Council stated that: "Aviation is an R&T-intensive industry." ". . . future capability rests solidly on today's aeronautics R&T investment." ". . . continued reductions in funding for aeronautics R&T may have irreversible consequences. Once the [leadership] position of the United States in aeronautics is lost, it will be exceedingly difficult to regain because of the difficulty in reassembling the infrastructure, people, and investment capital."

Since the publication of that report, NASA funding for aeronautics research has continued to decline. If the current low level of funding for NASA aeronautics research continues, it is a certainty that the United States will not remain a world leader in aeronautical science and technology for either civil or military applications.

THE NASA AERONAUTICS BUDGET PICTURE

As mentioned earlier, the NASA aeronautics budget was reduced by about one-third in FY99 and FY00. Almost all work on developing the technologies for a future U.S. supersonic airliner was terminated. In addition, the Advanced Subsonic Technology Program, which was focused on developing the pre-competitive technologies that would ultimately make U.S. aircraft more efficient, improve noise and emissions, and reduce ticket prices, was also cancelled. We believe that both of these classes of aircraft will be very important to U.S. civil and military competitiveness in the future, and that new technologies unique to NASA's expertise and test capability will be required. Although some of the work from these programs has continued in other programs, we believe that much more work is needed.

In FY01, the aeronautics budget essentially remained stable with respect to FY00. The Bush FY02 budget proposes two additional major reductions. The elimination of all NASA rotorcraft research and, as best we can understand it, essentially all military aviation technology. This effectively severs the long-standing, cost-effective partnership on which the U.S. depends for military superiority. Although we believe the Aviation System Capacity program, the Aviation Safety program, and the Small Aircraft Transportation System program are adequately funded in FY02, the net effect is an additional 20% reduction to the overall NASA aeronautics program.

We understand that the budget pressures facing NASA are severe, and we understand the need for the development of new technologies for more efficient space launch capability. However, we do not believe that the nation can afford to sacrifice NASA's traditional aeronautics research role to satisfy space program demands.

REGAINING U.S. PREEMINENCE IN AERONAUTICS THROUGH NASA RESEARCH

The good news is that NASA has the capability to solve most of the nation's aeronautics problems. Research currently underway can be expanded to capitalize on the expertise and national test facilities already existing at the NASA Aeronautical Research Centers. NASA has programs underway that are aimed at making improvements in many of the key areas. These programs can be significantly expanded and other new programs can be developed to meet the long-term national technology needs for civil and military aviation.

Aeronautics is not a mature science and many new concepts are emerging from NASA research that could revolutionize aviation. Some examples are: very-large blended-wing-body aircraft for both civil and military missions; a transpacific supersonic airliner that is both economically viable and environmentally friendly; an aerospace plane that can fly cheaply to space; technologies for advanced unpiloted military aircraft; aircraft that can change their shape seamlessly in flight; advanced rotorcraft or tiltrotor aircraft that can offload the runways at our hub airports; a new generation of safe and easy-to-fly personal aircraft; advanced cockpits with synthetic vision, satellite navigation, and highway-in-the-sky technology; and, reduced runway spacing requirements and vortex control technology to increase hub airport throughput.

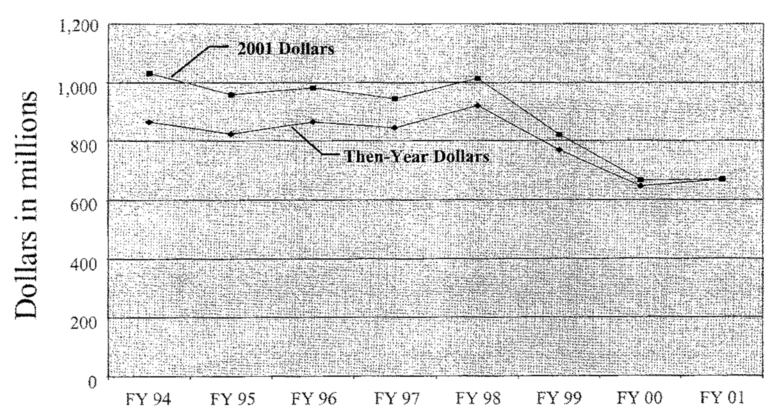
We believe that NASA's "Aeronautics Vision for the 21st Century" will agree with the problems facing U.S. aviation that we have outlined here, and that NASA can provide the solutions that are so desperately needed. We do not agree that the vision can be realized by reinvesting the already sub-critical aeronautics budget into a few potentially revolutionary new technologies. NASA must maintain a complete aeronautics program encompassing all of the relevant aeronautical disciplines and vehicle classes. Funding needs to be restored to the pre-1998 levels and the program revitalized to provide the desperately needed long-term technology solutions to America's civil and military aviation needs.

We believe that this can be accomplished only by a doubling of the aeronautics portion of NASA's budget over the next 4 years, from about 730 million dollars in FY01 to about 1,400 million dollars in FY05. (See attached charts 6 through 9.) This is not an unreasonable increase, considering the fact that NASA's aeronautics budget in FY98 was about 1 billion dollars in terms of FY01 dollars.

In conclusion, we believe that NASA's overall budget needs to be increased to provide the funds necessary for a world-class aeronautics research program—that, as a result, it will no longer be necessary to rob aeronautics in order to pay for space projects—and that the U.S. will regain its historic position as the world leader in both civil and military aviation. Our national economic wellbeing depends on it, our national defense depends on it, and it will impact the quality of life of all Americans. As we approach the one hundredth anniversary of the Wright brothers first flight at Kitty Hawk, NC in 2007, let it be said of this Congress that they had the wisdom to invest in the systematic research methods first demonstrated by Orville and Wilbur and practiced by NASA, that maintained U.S. world leadership in both aeronautics and space.

NAST
NASA AERONAUTICS SUPPORT TEAM

NASA Aeronautics Funding History



NAST
NASA AERONAUTICS SUPPORT TEAM

Aero Related Budget Comparison

$ in millions per year

	FY01		FY02	
Focused Programs		238.3		245.6
Aviation System Capacity	68.4		100.6	
Aviation Safety Technology	70.8		70.0	
High Performance Computing	22.2		---	
Ultra Efficient Engine Technology	47.9		40.0	
Small Aircraft Transportation System	9.0		15.0	
Quiet Aircraft Technology	20.0		20.0	
R&T Base Programs		494.4		530.0
Vehicle Systems Technology (Space & Aero)	151.6		157.5	
Propulsion & Power	85.8		94.8	
Rotorcraft	31.6		---	
Aviation Operations Systems	17.4		---	
Flight Research	83.3		82.4	
Computing, Info. & Comm. Tech.(Space & Aero)	---		195.3	
Information Technology	118.4		---	
Test Facility Upgrades		6.0		0.0
Total		732.6		775.6

NAST
NASA AERONAUTICS SUPPORT TEAM

NASA Budget Narrative

Aerospace Vehicle Systems Technology (Space & Aero)

Aerospace Vehicle Systems Technology (AVST): In FY 2002, the AVST program continues its healthy balance between aeronautics activities and contributions to space transportation. Technologies in the areas of safety, environmental compatibility, general aviation, next generation design tools, experimental aircraft and access to space will be continued. Tasks for space transportation will be completed, including the second flight of the Mach 7 Hyper-X vehicle and the first flight at Mach 10.

Assumption: 50% Space & 50% Aeronautics
Total Funding = $157.5
Aero Portion = $78.8

NASA AERONAUTICS SUPPORT TEAM

NASA Budget Narrative

Computing, Information & Communications Technologies (Space & Aero)

Computing, Information & Communications Technologies (CICT): In FY 2002, CICT will see the completion of major steps towards autonomous science exploration, including the development of the conceptual high-level autonomy architecture for planetary rovers. A collaboration has been formed with the Mars 2003 mission team to demonstrate the benefits of advanced planning and scheduling technology for automated sequence generation. The technology will be integrated into existing tools to be used by the mission and will be considered for incorporation into the mission following the demonstration.

Assumption: 2/3 Space & 1/3 Aeronautics
Total Funding = $195.3
Aero Portion = $65.0

NASA AERONAUTICS SUPPORT TEAM

FY 02 Aeronautics Budget

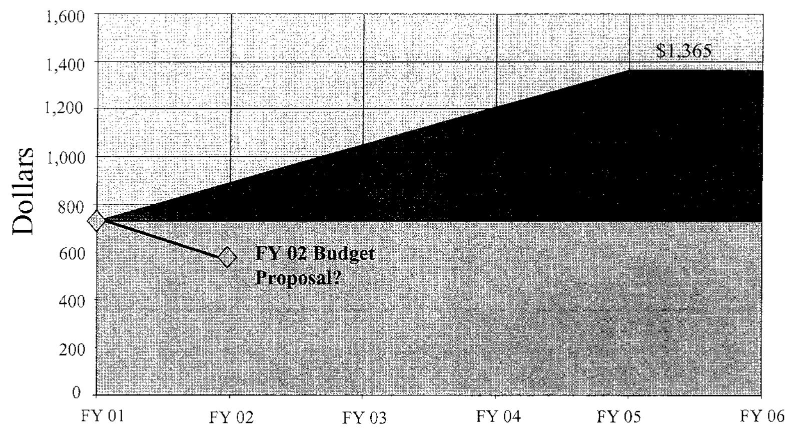
$ in millions per year

Focused Programs		245.6
Aviation System Capacity	100.6	
Aviation Safety Technology	70.0	
Ultra Efficient Engine Technology	40.0	
Small Aircraft Transportation System	15.0	
Quiet Aircraft Technology	20.0	
R&T Base Programs		321.0
Vehicle Systems Technology (Aero Portion)	78.8	
Propulsion & Power	94.8	
Flight Research	82.4	
Computing, Info. & Comm. Tech.(Aero Portion)	65.0	
Test Facility Upgrades	0.0	
Total		566.6

NAST
NASA AERONAUTICS SUPPORT TEAM

Recommended Aero. Ramp-Up

$ in millions



1/2/01

NAST
NASA AERONAUTICS SUPPORT TEAM

Required Augmentations

$ in millions per year

	FY 01 Budget	Additional Funds Required Over 4 Years
System Capacity	59.2	20.8
Safety	70.0	10.0
Environment		
Noise	18.3	61.7
Emissions	50.0	50.0
Competitiveness		
Subsonic Performance	0.0	75.0
Small Aircraft Transportation	9.0	30.0
Supersonic Technology	0.0	60.0
High Performance Computing	24.2	0.0
National Defense		
High Performance Aircraft Technology	0.0	40.0
R&T Base Programs	500.4	286.0
Total	731.1	633.5

NASA AERONAUTICS SUPPORT TEAM

Required Augmentations

R&T Base $ in millions per year

R&T Base Programs	FY 01 Budget	Additional Funds Required Over 4 Years
Vehicle Systems Technology	149.7	25.3
Propulsion & Power	85.2	14.8
Rotorcraft	26.7	23.3
Revolutionary ATM System	17.5	62.5
Flight Research	79.9	20.1
Information Technology	125.4	0.0
Test Facility Upgrades & Operations	16.0	100.0
University Aero. Centers of Excellence	0.0	40.0
Total	500.4	286.0

NASA AERONAUTICS SUPPORT TEAM

Additional One-Time Investment

- New U.S. wind tunnels are a high priority need
  - Europeans have invested heavily in new wind tunnels
  - New European tunnels are better than older U.S. counterparts
  - U.S. companies are now forced to test in Europe in order to be competitive
  - Security of U.S. data obtained in Europe can be compromised
  - Numerous national studies have documented need for new U.S. wind tunnels
- Cost of new wind tunnels is about $1 billion
  - Previous studies need to be updated
  - Would be funded over several years

Senator ALLEN. Thank you, Mr. Harris. We will ask you questions after everyone has completed their remarks.

Mr. Swain is next, Mr. David Swain, Senior Vice President for Engineering and Technology, and President, Phantom Works, the Boeing Company.

STATEMENT OF DAVID O. SWAIN, SENIOR VICE PRESIDENT, ENGINEERING AND TECHNOLOGY; PRESIDENT, PHANTOM WORKS, THE BOEING COMPANY

Mr. SWAIN. Thank you very much, Mr. Chairman and Senator Breaux, for letting me testify today. I want to start by making three main points; first, that aerospace research serves an important public good. It is a foundation for our national security and a key element in the economic growth of our country. Also, a robust program is key in attracting, developing and retaining the intellectual capital on which our Nation will depend for global aerospace leadership.

Second, the Boeing Company strongly endorses Administrator Goldin's goal to reinvigorate NASA's role as an enabler of breakthrough aerospace research and technology. Over the years, NASA's leadership and investment has significantly advanced aerospace technologies and reduced the cost of application. These enabling technologies produce significant public benefits by improving the safety, efficiency, and environmental performance of aerospace products and services.

Third, the last several years have seen a decline in government investment in aerospace technology, both in NASA and at the Department of Defense. I view this trend with concern, knowing the challenges that lie ahead of us and the competition from our competitors abroad. Aerospace research and technology and NASA's contribution over the years have been a strong component to our national security posture. The quickened pace of technology development and movement around the world in the future global environment that is uncertain, makes it even more important today to have a strong technology base that provides future options for our defense than it did ever before.

Looking back, that technology base has led to products that we see today and emerging products, such as the unmanned air vehicles that are now readying for development in our defense. Aerospace research contributes both to the national and economic security and the pursuit of safer, more reliable, lower-cost access to space. Our defense is getting more critically dependent on space, as well as economic development.

In the age of instant global communications, our economy is very dependent on space and its ability to use it when needed. Fundamental technology challenges remain in this area, including lightweight, low-cost airframes, propulsion system breakthroughs, and health management systems. I do agree with Mr. Goldin that many of these same technologies are as applicable to aeronautics as to space. Aerospace research and technology have significant implications for air transportation, which is the basic enabler to our current economic growth. First among the challenges is our national aviation system, which is approaching the limits of its capacity at the same time traveler demand is increasing.

The situation, underscored by passenger delays, increases serious economic implication on the airlines—is approaching a crisis that demands a comprehensive effort with the highest national priority. Another dimension to air transportation is the demand for environmentally responsible aviation, including control of noise emission and more efficient airplanes and airplane operation. As mentioned earlier, the European aerospace vision identifies approximately $90 billion over the next 20 years to take them to aerospace leadership.

Over this same period, our company will not stand still. We will invest over $50 billion in research and development, but I have to admit most of this is product-specific and not research and technology. We will invest about 10 percent, or closer to $5 billion, in basic research and technology, which is small, certainly compared to the European commitment. So as critical as before, it is important to our industry and our country that the government take a critical role, particularly in research and technology, that is focused on breakthroughs that can lead us into the next generation of vehicles and support systems.

In addition to NASA's role as the innovation engine, we strongly support focused NASA efforts to integrate breakthrough technology for systems solutions. Each of Boeing's top aeronautical and research technology programs demand and benefit from the synergies of an integrated approach and are well-aligned with the NASA budget that is before this Subcommittee; these are air traffic management; 21st century vehicle technology; and a space launch initiative.

I understand budget constraints. I live with those every day in our business. I am not optimistic we can make huge budget changes in this year, but I think it is important that the dialogs be started; that we understand the impact the trend has had to date and what the impact of continuing to reduce budgets over time will mean, relative to our competitive position and our ability to have a strong defense.

It is time to start a dialog. I thank this Subcommittee for beginning that dialog, where both government and industry and universities interchange and develop a plan that will ensure that we have a robust program that will support our national security and will support our commercial aviation business in the future.

Mr. Chairman, thank you for your time and listening.

[The prepared statement of Mr. Swain follows:]

PREPARED STATEMENT OF DAVID SWAIN, SENIOR VICE PRESIDENT OF ENGINEERING AND TECHNOLOGY; CHIEF TECHNOLOGY OFFICER, THE BOEING COMPANY

Thank you Mr. Chairman and Members of the committee. I am David Swain, Senior Vice President of Engineering and Technology and Chief Technology Officer for the Boeing Company. I am pleased to testify in support of robust aerospace research and development funding and NASA's Aerospace Technology Enterprise.

I want to leave three points with you this afternoon.

• First, aerospace research serves an important public good. It is a foundation for national security and economic growth, not least because of the role of aerospace research in attracting, developing, and retaining the intellectual capital on which the nation will depend for global aerospace leadership.

• Second, the Boeing Company strongly endorses Administrator Goldin's goal to reinvigorate NASA's role as the enabler of breakthrough aerospace research. Over the years, NASA leadership and investment have significantly advanced aerospace technologies and reduced the risk of application. These enabling technologies have produced significant public benefits by improving the safety, efficiency, and environmental performance of aerospace products and services.

• Third, the last several years have seen a decline in government investment in aerospace technology, especially funding related to aeronautics in NASA and the DoD. I view this situation with concern in view of the challenges that lie ahead of us in a future characterized by uncertainty and change.

Aerospace research is important to national security and economic growth.

Aerospace research and NASA's contribution over the years have been a strong component of our national security posture. The quickening pace of technology development around the world and a future global environment that is quite uncertain make it even more important to invest in technology research that reduces risk and enables options for future needs. Looking back, it is exactly this type of research, conducted by NASA in concert with the Department of Defense, that has advanced options such as unmanned air vehicles, which are ready today to transition into development.

Aerospace research contributes to both our national and economic security in its pursuit of safer, more reliable and lower cost access to space. The military is critically dependent today on space based assets, and is expected to become more dependent in the future. In the age of instant global communications, our economic well being is also dependent on space based systems. Fundamental technology challenges remain in this arena, including light weight, low cost airframes, propulsion, and health management systems.

Aerospace research has significant implications for air transportation, which is a basic enabler for economic growth. First among the challenges is our national aviation system, which is approaching limits in its capacity at the same time that traveler demand is increasing. This situation, under-scored by passenger delays with increasingly serious economic implications, is approaching a crisis that demands a comprehensive effort with the highest national priority. As you are aware, Boeing has established a new business unit dedicated to air traffic management, and we are working with NASA, the FAA, and other stakeholders to define a new operational concept to improve safety, increase capacity and reduce delays.

Another dimension of air transportation is the demand for environmentally responsible aviation, including control of noise, emissions, and more efficient airplanes and airplane operations. NASA pre-competitive research is addressing this public good with focused programs that involve all the stakeholders.

Boeing strongly supports NASA's role as the enabler of breakthrough aerospace research.

The European Aerospace vision identifies $90B or so from public and private sources over the next 20 years for aerospace research and technology. Over the same period, Boeing will invest $40B–$50B in Research and Development. Most of this will be product focused, with about $4B–$5B related to long term research and technology. Even then, longer-term research must satisfy certain business constraints. It is therefore critical that government, and particularly NASA, continue its historical role of supporting break-through, pre-competitive research that has a longer time horizon than industry can support—10 years or more—before it is mature enough to be considered for transition to product development.

In addition to NASA's role as an innovation engine, we strongly support focused NASA efforts that integrate breakthrough technologies for system solutions. Each of Boeing's top aeronautics research and technology priorities demand and benefit from the synergies of an integrated approach, and are well aligned with the NASA budget that is before the Subcommittee. They are air traffic management, 21st century air vehicle technology, and the space launch initiative.

Projected air travel threatens to overwhelm an already congested air traffic network calling for a new, system level approach incorporating space-based assets integrating accurate navigation and information technologies. Research and technology investments are needed in modeling and simulation, architecture studies and tools.

NASA's long-term investments for aeronautics research and technology will be applied to 21st century commercial and military air vehicles. The goals for 21st Century air vehicle technologies are increasing performance, maintaining an outstanding safety record, improving reliability, and reducing development and production cost and cycle time. Breakthrough 21st Century air vehicle technologies will be pursued with an integrated (wings, propulsion, and fuselage) approach within a 10 to 20 year vision.

Similarly in the space launch arena, NASA's long-term investments provide an opportunity for technology breakthroughs that will change how we think about meeting the safety, reliability and affordability goals for future commercial and military access to and use of space.

Funding for US aerospace research is declining in a competitive global environment.

Notwithstanding the significant implications of aerospace research for national security and economic growth, there are some who question the government's role in this arena. This is not the case with our aerospace competitors in Europe and Asia. Europe, for example, prizes global aerospace leadership and a world class transport system as a goal by 2020. The goal is underpinned by a supportive public, favorable policy regulation, and a rigorous research agenda. To quote from the European Vision: "European aeronautics has grown and prospered with support of public funding, and this support must continue if we are to achieve our objective of global leadership."

More troublesome than the actions of our global competitors are recent trends in funding for aerospace related science and technology in NASA and in the DoD. Industry associations, including the Aerospace Industries Association, and concerned aerospace professionals have documented these trends. Statistics of particular concern to me are the amount of national funding going into aerospace research and development, which has halved over the past 20 years, and NASA's investment in aeronautics research, which has declined 40% in the last 6 years. These trends put in future jeopardy the aerospace industry's position as the most positive contributor to the trade balance of any industry in the United States. The trends are already manifest in declining global market share for US aerospace companies, and translate directly into fewer American jobs and reduced US tax revenues.

Budget constraints mean fewer technology initiatives and fewer prototype demonstration programs in DoD and NASA. This has translated into fewer opportunities to develop and transition leap ahead technologies to address national needs, and importantly, fewer opportunities to attract and engage a new generation of aerospace talent on which our nation will depend. A strong "base research and technology program" in aeronautics and aerospace is essential for providing the foundation on which to build a wide array of specific applications that serve the national interest.

Given today's constraints on federal resources, I do not expect the funding gap for aerospace research and technology will be closed in a significant way this budget year. However, I do strongly recommend that the Congress, at a minimum, fully support the NASA aerospace research and technology budget. Moreover, I recommend that the Administration and the Congress take a long-term view of the nation's investments in aerospace technology and the return on those investments to the American taxpayer. This view should consider the benefits that have resulted from past investments in aerospace technology, and what the consequences to national security and economic growth will be from not investing in the future.

Mr. Chairman, it has been some time since Boeing has testified in support of aerospace research and technology funding. I sincerely appreciate your initiative in providing us this opportunity. My hope is that today's proceedings are the start of a national dialog on this important subject.

Thank you.

Senator ALLEN. Thank you, Mr. Swain, Mr. Deel, Mr. Bolen, and Mr. Harris for your testimony. I am going to ask a few questions. Most of the questions I was going to ask, each and every one of them, you all actually addressed in your statement. Clearly, each and every one of you, in a variety of ways, you understand and certainly strongly support NASA. As far as the aerospace, aeronautics aspect of it, Mr. Harris, in particular, NASA Langley, but clearly hearing from Mr. Deel, as far as Lockheed, from the Michoud; is that how you would pronounce it? Michoud? Michoud?

Senator BREAUX. Michoud.

Senator ALLEN. C'est bon.

[Laughter.]

Senator ALLEN. At any rate, your comments are important, and how that affects Lockheed really does mean a great deal, I think, to all of us. We are beginning a dialog. That was the whole purpose of this hearing, was to learn more, not just from NASA, but from those who work with NASA, whether it is general aviation or big, big companies such as Boeing and Lockheed. The question I asked Mr. Goldin, which I think is very important for all of us, is to find ways—and you do it in the private sector all the time—to measure your investment.

Research and development does not always have a quick turnaround, and each of your companies has a certain amount allocated for research and development, but to the extent we are going to be investing more taxpayers' money logically, so we keep that competitive edge for our national security, make sure we have the industrial infrastructure for aviation in the future, and the next generations, using times evolutionary and revolutionary, but all the advances, it is absolutely essential for our Nation, for our economy, for our quality of life, for our environment, for jobs and obviously for our national security, as well. But as we make these investments, it is very important—and if any of you can share with us ways to measure it—Administrator Goldin at least said, "Here are our set goals, here is what we want to do in reduction and delays, and lost time or accidents, or capacity and fuel efficiency and so forth."

To the extent that you could share with me and with us, ways that we can see we are getting that bang for the buck, that return on the investment for the taxpayers, I think is absolutely essential, because you do not want to squander the taxpayers' money. I think everyone recognizes, who has a scintilla of knowledge, how important this is for our country and our future. But nevertheless, spending money alone is not the only answer. Spending it intelligently, and also with the credibility that you are getting a return, and that is why I like measurement or some performance guidelines. If any one of you all or each of you could share with me what sort of performance measurement could we look at over the years as we go forward with the future appropriations, say here are going to be our benchmarks, here are our measurements, what would you all utilize or suggest that we utilize for those performance measurements?

Mr. Bolen.

Mr. BOLEN. Mr. Chairman, the General Aviation Manufacturers Association has a subcommittee that meets with NASA on a regular basis, and we discuss the programs that relate to general aviation specifically. I think we have been pleased over the past several years about the progress we are making. Administrator Goldin talked a lot about the goals that he has, and I think everyone who has worked in NASA or worked with NASA or worked with Mr. Goldin in any capacity, knows that the goals that he sets are not easily achieved. He makes you stretch and stretch often. Nevertheless, I think his vision is very positive and it does drive us.

What we are trying to do at GAMA is make sure that when NASA begins a research program and works through a multi-year research program, that we find out whether scientific research will yield anything of positive value to the companies, and are the companies willing to invest in it? The general aviation programs have a private sector match, which I think is very, very positive. It means put your money where your mouth is in terms of the research, and I think that is very good. I think it is very important that we make sure that once a program is started, that it does not just continue and take on a life of its own; that every year, during the appropriations process, we talk about the progress that is made and we talk about whether the funding that we decided 5 years ago was necessary is maybe too much or too little, should be stopped or should be accelerated.

It is very difficult sometimes with basic research to map things out over a long-term period. Sometimes things come quicker, sometimes they take more time. But I think there is a general feeling in industry when things are going in the right direction and when we are on the right track. I will commit to you and to this Subcommittee, to be available to you and share with you what our Subcommittees are finding as we try to work through NASA's programs. And I would just expand that a little bit more. We do not just work with NASA. When we are following a technology, following research, we are also trying to work, as NASA is, with the FAA, to make sure whatever it is we get is something that is certifiable and can be part of our national air transportation system.

Mr. SWAIN. I would like to add measurement in this area is difficult. I think the most important thing is to set breakthrough goals, which the administrator talked about, and then a research agenda that is focused on those goals; then we could measure periodically are we making progress or not? When you set breakthrough goals, and I remind myself of my own job, some percentage of the research projects we start I am going to stop, because they will not work out, because you do not know exactly what was the combination of technologies, when put together, that will yield the 35 or 50 percent improvement.

So I think we have to set goals, a research agenda, and then track to see if the overall agenda is heading in a direction to meet the goals. If you try to measure any one particular program, if we got a robust program, I think half will fail. If all succeed, we are not stretching and we will find no breakthroughs. So there is the dichotomy we are all faced with. When we get to investing in a new product, it is very clear. We are confident of the technology, the research is done, we have got have a good internal rate of return, but the fundamental research up front, we have just got to ensure ourselves we have got a portfolio that will give us the outcomes that we hope for and we set enough challenges that will require new ways of thinking, real breakthroughs that will come from our scientists and engineers.

Senator ALLEN. Thank you.

Senator Breaux, do you have any questions?

Senator BREAUX. Thank you very much. I thank the panel for being with us this afternoon. Let me ask Mr. Deel a question. You heard the exchange I had with Mr. Goldin on the X-33, and you heard his response. Do you think we still need to be pursuing that? Do you agree with his assessment as to why it was canceled?

Mr. DEEL. We agree that NASA made a pragmatic decision because of budget pressures. What I heard Mr. Goldin say was the technology was a challenge, it was a stretch. It was a program that was started with an intent to revolutionize the launch business, to increase the reliability of the launch vehicle and significantly reduce the cost. That fits the criteria of the stretch program.

Senator BREAUX. I heard what he said. I was wondering what Lockheed Martin thinks about that.

Mr. DEEL. The program encountered a failure and a setback. NASA reduced the funding. I would say that Lockheed Martin is encouraged by NASA's willingness to work with the DOD, so that the money that has been invested and the technologies that are being put in place can have an opportunity to fly and demonstrate their usefulness as they go further.

Senator BREAUX. What do you think we got out of the money that was spent at NASA on the X-33?

Mr. DEEL. We have got lightweight tank structures. We have gotten a linear aerospike engine that is being tested at Stennis. The proof of that engine's performance capabilities is demonstrated when it flies, not on the ground. We have got vehicle health monitoring systems embedded in the system. It is a revolutionary concept. We certainly were disappointed when the program was not funded. We certainly would welcome an opportunity to pursue it.

Senator BREAUX. What is a ballpark split between the amount of tax dollars contributed to what was developed, versus the amount the private sector contributed?

Mr. DEEL. I believe the numbers were a NASA commitment on the order of $900 million and we had, I believe, about $300 million of company investment in the program to date.

Senator BREAUX. A 3:1 split.

Mr. Harris, talk to me about some of your concerns. You raised concerns about a lot of issues that you feel are not going to be done. You talked about upgrading wind tunnels and a number of other areas. If NASA does not do this, who does it?

Mr. HARRIS. If NASA does not do it, it will not be done.

Senator BREAUX. In the areas that you mentioned, would it not be done because there is just not an economic short-term benefit for the private industry to move into this? It is like it is pure research as opposed to applied research? I mean, if it is important and it is good technology, why does not the private sector do it themselves?

Mr. HARRIS. Well, specifically with regard to test facilities, such as wind tunnels, the government has something like $3 billion invested in government-owned wind tunnels that were designed primarily for aeronautics research. They are also used very heavily in the space program. The space launch vehicles are all tested in those wind tunnels. The shuttle, in its development phase, was one of the heaviest users of NASA's wind tunnels.

Senator BREAUX. If you listen to what Dan Goldin was saying, he said, "Look, NASA wants to look at the long-term." Certainly, it would seem to me that wind tunnels are short-term. We are testing models that we have out there now, and basically doing the same type of planes, fixed-wing aircraft. It seems that is more short-term. Why wouldn't the manufacturers of the planes that are going to be utilizing wind tunnels, why wouldn't they build their own wind tunnels?

Mr. HARRIS. The idea of the morphing airplane that Mr. Goldin talked about, those things have to be tested in wind tunnels. They can be also tested analytically and models of the revolutionary new concepts will have to be tested in wind tunnels. The development of prediction capability, in order to predict the performance of the radically new kinds of vehicles, those computational tools have to be calibrated by tests in wind tunnels and structural labs and other kinds of facilities.

Senator BREAUX. From a global standpoint, I am always interested in the amount of cooperation, both legislatively and financially, between foreign governments and their private sector manufacturers, particularly in aerospace activities. It would seem to me that when NASA moves away from some of that type of assistance, it makes our companies less competitive from a global standpoint. Look at the close relationship between governments and some of the things that are happening in Europe, with their operations with government, joint-venture type operations. Do you agree with that? Can we be competitive if NASA does not take the lead in some of these types of research programs?

Mr. HARRIS. Well, it seems to me the handwriting is on the wall. If you read the European report, their vision for 2020, they State the compelling economic reasons to invest in aeronautics, and what the payoff is to their governments and their society for doing that. I think that it is clear that they realize that the benefits that the United States has had in the past, because we dominated the world in aeronautics, and they see an opportunity to gain that lead, and have those benefits for themselves in the future.

Senator BREAUX. I think when you add it all up, the favorable financing terms that are provided sometimes by governments, the financial investment—the Airbus program is an example of all those things coming together—it makes it very difficult for our companies to compete, and I am concerned. It seems like our biggest competitors are moving in the opposite direction than we are right now. It gives me some concern for the future.

Ed Bolen, private sector research; I mean, you talk about how important it is that NASA do some of the things that benefits your general aviation manufacturers. Do you have any comparison, Ed, from what your GAMA members were spending on these type of activities, say, 5 or 10 years ago, as opposed to what they are spending now on the type of research that is necessary to develop the aircraft for the future? Are you spending more? Are you spending less? Are you spending about the same?

Mr. BOLEN. Several years ago, in the 1980s and early 1990s, the general aviation industry was really on its back. We had gone from manufacturing about 17,000 aircraft a year in 1979, down to less than 1,000 in 1994. So we went through a period of time when simply surviving was all we were concerned about. There was not a lot of investment in new products. There was only a hope that tomorrow you would be there in existence, and maybe the day after.

That turned around in 1994. We passed product liability legislation that has led to increased investment in the general aviation industry. Sales have tripled, and we have begun investing much, much more in new technologies. We went through a period of time between 1995 and the year 2000 where, in that 5 years, we brought more new aircraft models to the market than we had in the 15 years previously.

We are seeing new engine technologies and great breakthroughs in terms of avionics, which are helping us with our situational awareness. So we think we are making quantum leaps forward. For the first time, we are beginning to see brand-new aircraft companies that are coming into general aviation, that are certifying new airplanes, and we are seeing that both at the entry-level with piston aircraft and also at the far end, where Boeing now has a business jet. So all across the general aviation spectrum, we are seeing investment.

We are seeing investment in new aircraft models, in new engine technology, some of those that have been directly related to investment by NASA. We are certainly seeing it in terms of avionics. So I think in terms of what is happening in general aviation, it is nothing really short of a revolution that we have seen over the past 5 years.

Senator BREAUX. I guess the final point—I do not want to belabor it—is how much is all of this new activity in terms of new aircraft, new frames, new engines, and new avionics is coming from the industry and the private sector, versus how much is help from government tax dollars through NASA or through other Federal programs?

Mr. BOLEN. Well, I think it is very much a team approach, and let me give you one example. NASA had general aviation program called GAP, the General Aviation Propulsion Program, which worked with a couple of different companies at investing in revolutionary, breakthrough technologies in terms of engine propulsion. What we are seeing in that, which was a program that had a 50–50 match between NASA and industry, is we are seeing a breakthrough turbine technology by Williams International, a substantially new—radical new propulsion system, that is leading to a new aircraft company being formed that is going to build a platform around that engine.

So I think what we are seeing is the NASA dollars are having an impact there. It is having an impact with the established manufacturers, like Cessna, who are adopting new technologies on their aircraft, but we are also seeing NASA's investment reflected in new airplanes manufactured by companies like Cirrus Design and Lance Air, which did not exist 5 years ago. So we are seeing it both in terms of technologies, and in terms of spurring entirely new companies that see the potential in the technology and are willing to make a business investment in it.

Senator BREAUX. I thank the panel. Thanks, Ed.

Thank you, Mr. Chairman.

Senator ALLEN. Thank you. Let me add one final question, and this is for Mr. Harris. I obviously understand and agreed, even in my opening remarks, with some of the concerns, the competitiveness. You obviously do not feel that the Commission on the Future of the U.S. Aerospace Industry, as required last year by the defense authorization bill, is properly structured to support the concerns of the aeronautical community. That was one thing that I got from it. You say that some of what needs to be done is we need to double the aeronautics budget. We do not, I do not think, have a plan to compete with Europe's plan, their vision for 2020, and so forth.

One thing Mr. Goldin—I tried to do, is to get him to say what are the priorities in there—and obviously, Mr. Harris, you have a great deal of expertise. Your philosophy seems to be very close in looking at the facts, is the way I look at it. If we are going to have this expected aeronautics vision for the 21st century that NASA will be releasing this fall, which research programs do you think will be necessary to ensure that America either has a continued leadership role, or at least a good competitive role in aeronautics? Where would you see the key priority areas being?

Mr. HARRIS. I think certainly among them, a research program to solve the problem of efficient supersonic flight.

Senator ALLEN. By that, what do you mean efficient? Fuel-efficient?

Mr. HARRIS. I am talking about aerodynamic efficiency, fuel efficiency and structural weight efficiency, the whole thing. I think that one of the big reasons that Boeing made the decision not to proceed with the supersonic transport was that the technology simply was not ready at the time to produce an efficient machine that could meet all the environmental constraints.

There are a lot of things that impact when a company like Boeing can proceed with an airplane. The technology has to be ready, No. 1; the market has to be ready, and then financing and other things all have to be ready, and all of those things have to come into alignment. But the financing and the market are not really NASA's concern. It seems to me NASA's concern is to take the leadership in developing the key technical solutions that make the technology ready, so that when a company decides that their market is ready, the technology will be in hand to proceed with confidence. So I think the supersonic technology certainly would be high on my list.

I think another one that would be high on my list is NASA's support of military aviation technology. I think that area has been reduced significantly in recent years. It is one where I think that the partnership between NASA, the NASA laboratories, and the DOD laboratories, has been one of the keys to our success in military aviation technology.

Senator ALLEN. Although NASA cannot do that suasponte, or on their own; right?

Mr. HARRIS. It is a partnership. I mean, it is interesting that the same act of Congress that established the first NACA laboratory—that same act of Congress established the first Army Air Corps research laboratory at Wright Field, and that partnership begin in 1917 and has existed until today. It has been a very important one.

Another area, that I would put high on my priority list would be a revitalization of NASA's experimental test facilities. I think Dan Goldin, he did not say it today, but he has said it in other fora, that we need to take a look at the national test capability and what is really needed. There were several studies a few years back that looked at this issue. I think a lot has changed since those studies were done and we need to revisit those studies. What is the national capability that we really need and how can we best attain that capability? Maybe some of it is by modifying existing facilities. Maybe we need to build some new facilities, and with that, maybe we can actually close some of our older facilities and get cost offsets by doing that.

And then I think there is one final area that I would put high on my priority list, and I am encouraged by looking at—in the fiscal 2002 budget, there is some funding for this in the NASA budget, but I would go beyond what they are proposing to do, and that is in expanding the idea of university centers of excellence in the technical disciplines, coupled with the NASA research centers. We have lost so much of our talent in recent years, due to retirements and also due to the fact that we have been unable to hire young people in recent years.

One way to regain that quickly is by forming an alliance with the universities, where graduate students and professors can be brought in to work with the NASA laboratory people, to help that situation. I think those would be my top priorities.

Senator ALLEN. Thank you, Mr. Harris.

I want to thank all the panelists, Mr. Swain, Mr. Deel, Mr. Bolen, Mr. Harris. Thank you for your insight and waiting through this long hearing. But this is a very, very important Subcommittee hearing, and we all look forward to working with you, not just when there is a hearing. Our doors and offices are always open to you all. Thank you all so very, very much. Hearing adjourned.

[Whereupon, at 4:47 p.m., the hearing was adjourned.]

APPENDIX

PREPARED STATEMENT OF THE AVIATION R&D TASK FORCE OF THE AEROSPACE DIVISION, ENVIRONMENT AND TRANSPORTATION GROUP COUNCIL ON ENGINEERING

Mr. Chairman and Members of the Subcommittee:

The Aerospace Division of the American Society of Mechanical Engineers (ASME International) welcomes this opportunity to present our views on the nation's critical aeronautics research and development needs.

ASME is the premier organization for promoting the art, science and practice of mechanical engineering in the world. It conducts one of the world's largest technical publishing operations, holds some 30 technical conferences and 200 professional development courses each year, and sets many industrial and manufacturing standards. This testimony represents the considered judgment of the Aviation R&D Task Force of the Aerospace Division of the Council on Engineering, and is not necessarily a position of ASME as a whole.

We are concerned that a national commitment to sustain U.S. leadership in aviation research and technology has been lacking. While public demand for aviation transportation services is expanding, federal funding for civil and military aviation research is declining. Since 1998, the combined National Aeronautics and Space Administration (NASA) and Department of Defense (DoD) investment in aeronautics research and technology programs has been reduced by one-third, and there is concern that this trend will continue. Advanced technologies are needed to assure public safety and on-time flight schedules. Without stable investment in aviation R&T, U.S. market share in aviation products and services will decline, as will employment in the nation's aviation industry.

Specifically, we are concerned that a lack of long-term, stable federal funding for aviation research will jeopardize the nation's leadership in providing the technologies needed to develop the next generation aircraft, improve aviation safety, and reduce risk in the U.S. air transport infrastructure. In addition, a decline in federal support for NASA aeronautics research will diminish our universities' ability to attract and train the next generation of aeronautical engineers. In our view, NASA's aeronautics research and technology programs are essential to maintaining and strengthening U.S. global markets in air transportation products and services.

THE ECONOMY AND BALANCE OF TRADE

In February 2000, the National Research Council reported that the U.S. has been losing ground in world aerospace market share, falling from over 70 percent in the 1980s to 55 percent in 1997. Today this situation continues, as U.S. aerospace industries are being severely challenged by the European aerospace industry, which is garnering a significant portion of the U.S. market as well as of the world market. As reported in the March 2001 issue of U.S.A. Today, the European Airbus A380 555- passenger jet is expected to surpass the Boeing 747 in civil air transport markets. As a nation, are we spending our resources wisely to protect this vital segment of our economy? The present direction of decreased federal investment in aviation engineering, research, and development programs weakens the future economic competitiveness of the U.S. aviation industry.

Our international competition is certainly not subscribing to this course of action. In fact, according to a recently released report from the European Commission, efforts are well underway to overtake us in global air transportation markets.

In January 2001, European Research Commissioner Philippe Busquin unveiled a strategy paper called "European Aeronautics: A Vision for 2020." The strategy document, prepared by a group of 14 high-ranking individuals called the "Group of Personalities," charts the path for the European Union to become a global leader in aeronautics. It is a high priority on the European agenda.

The European Commission is proposing a strong dynamic program to achieve their vision of becoming a world leader in transport technologies, products and services. The Vision 2020 report—which presents goals in the present tense as if they have already been accomplished—states:

• "In 2020, European aeronautics is the world's number one. It's companies are celebrated brands, renowned for the quality of products that are winning more than 50% shares of world markets for aircraft, engines and equipment. Though coming in all sizes from multinational corporations to small and medium-sized enterprises, their position is built on formidable competitiveness in all areas, from research to design, from product development and support to manufacturing, operation and maintenance."

• "In 2020, European leadership will be evident on aircraft throughout the world. The industry in Europe is the leading developer and supplier of avionics systems and its engines and systems are simply the best. Its prowess also extends to air traffic management (ATM). Such has been the success of the "European solution" for ATM, that a de facto world standard has been created."

Clearly, our European colleagues intend to replace us as the world's leader in aeronautics. How will they finance this plan? As the report states:

• "Gradual realization of our ambitious vision must be facilitated by an increase in public funding. Although it is a preliminary estimate, total funding required from all public and private sources over the next 20 years could go beyond $95 billion."

While support for NASA aeronautics research is declining, this strategy plan calls for increasing European Union funding. We would argue that the U.S. has no comparable long-range plan for aeronautics research. In order to remain competitive, a clearly articulated vision for aviation research and technology is required.

In the National Science and Technology Council report cited earlier, an outline for the next generation Global Air Transportation System is articulated. However, the report does not consider issues related to the design of the next and future aircraft. What new and advanced technologies will be required to maintain and build the U.S. market share in this fiercely competitive and evolving global market? These issues and a host of others must be considered if the U.S. is to remain a major player in the ever-expanding international aviation enterprise.

The United States commercial aviation industries, faced with ever increasing global competition, are driven to focus the vast majority of their research dollars on projects that can affect near-term profits. The total global market for aviation-related products and services is estimated to be greater than $1.6 trillion over the next 20 years. The U.S. market share in this industry and the U.S. investment in advanced aviation R&D both continue to decline. In 1999, Airbus received 52% of the market share of orders for commercial jets seating over 100 passengers, exceeding Boeing for the first time. Yet in this same time period, $280 million was cut from the NASA aeronautics portfolio.

The cost to develop a new product such as a large transport aircraft can approach or exceed $15 billion. In the past, large investments in evolutionary significant-risk technologies, such as the transition to commercial jet aviation, have been accomplished through a partnering among industry, NASA (or its predecessor NACA), DOD and the FAA. These partnerships have proven to be an efficient means for maintaining the past U.S. lead in aeronautical technology with concomitant economic benefits. We are not suggesting that the government share the cost of specific commercial aviation developments, as has been the case in other countries. Rather, we recommend that NASA undertake high-risk, potentially high-payoff R&D, which then can become the basis for commercial enterprises. In our view, NASA must resume its intellectual and financial support for partnerships that sustain mid- and long-term innovative basic research in propulsion, materials and new structural concepts applicable not only to spacecraft, but also to future aircraft designs. Recent NASA/Boeing/University partnering in Blended Wing Body (BWB) technology and aerodynamics is a positive example. We encourage that adequate support be given for a robust aeronautics budget. These may well become the next big competitive arenas for the international aviation industry and the U.S. should be prepared to lead. What is certain is that government-private sector partnerships are essential to meeting these growing challenges.

THE U.S. AERONAUTICS INFRASTRUCTURE IS AT RISK

I would like to call the Subcommittee's attention to reports appearing in the *Aviation Week & Space Technology.* The editorial in the March 2000 issue makes the point that, "Aeronautics has become NASA's Stepchild," noting that "some of (their) readers advocate removing the *aeronautics* from NASA." The editorial goes on to reject this notion, stating that "the immediate answer is for the Administration to request, and Congress to grant, higher funding for NASA to make aeronautical research a higher priority."

We heartily endorse this view.

The impending risk to the nation's aeronautics infrastructure engendered by this decline in federal support for aviation R&D has been the subject of several recent studies. A February 2000 report from the National Research Council points out that the aeronautics segment of the economy "is becoming less competitive." The report notes that "the U.S. share of world aerospace markets fell from over 70 percent in the mid-1980s to 55 percent in 1997." In a report released in January 2000, the Air Force Association poses the question, "Does the Air Force have the resources and resolve to create the technological solutions that may be needed in another 20 or 30 years?" They answer this question by noting that "the paucity of S&T funding has helped erode traditional Air Force technology strengths. . . ." Again returning to the Aviation Week analysis, "NASA has virtually abandoned its research in military aviation, *a heritage that goes back some 82 years"* (italics added for emphasis).

In our judgment, these trends clearly should raise a flag in Congress.

NASA'S CRITICAL ROLE IN NURTURING AERONAUTICS RESEARCH AND EDUCATION

For the past 75 years, American universities have provided creative, skilled engineers for national defense and aeronautical commerce. The development of an efficient global air transportation system has been driven by American engineering. Students who have come from American university campuses to industrial and governmental facilities have been the source of an undisputed American commercial success; sales of aircraft and aircraft equipment accounts for one of the largest single positive balance of trade with other nations. According to a recent study of the Aerospace Industries Association, aerospace products accounted for nine percent of total U.S. merchandise exports in 1999. While the nation's total balance of trade has been negative since 1970, the aerospace industry's contribution to U.S. trade balance has been positive over this period of time, increasing by a factor of 20 (from $3.4 billion in 1970, to $62.4 billion in1999.) The partnership in the aerospace industry among the Federal government, industry, and universities has been one of the great success stories of the 20th century. In our view this is changing. And sadly, not for the better.

The commuter aircraft industry is dominated by foreign firms such as Bombardier in Canada, and Embraer in Brazil. In short, foreign countries believe that it is in their interest to establish and maintain a healthy, broad-based aircraft industry. The heart of this industry is a healthy academic source for workers and ideas; many of these engineers are educated in the United States. Our educational base has been declining and will continue to erode if we do not nurture and support basic aeronautics research in the United States.

While the aeronautics commercial enterprise has changed significantly over the past 50 years, so too have the investment requirements of the academic educational and research enterprise accompanying this industrial evolution. New technologies responsible for enormous increases in aircraft performance and system efficiency have required research universities to invest heavily in new faculty, new equipment and new computing resources. Some of these resources become obsolete after only a few years, requiring cyclical renewal. Both private and state supported universities have launched development programs to ensure the availability of best facilities and best teachers, but other budget demands have made modernization difficult.

Over the past several years, de-emphasis of long-term aeronautical research in both NASA and DOD has impaired U.S. universities' ability to maintain vibrant aeronautical engineering programs. As such, these universities are finding it increasingly difficult to contribute to near- or long- term progress in aviation R&D. As this situation continues, the nation is experiencing a diminishing pipeline of qualified aeronautical engineering students at both the undergraduate and graduate levels. Engineers and scientists do not consider aerospace a growth industry. Bomber and fighter design experience is vanishing. University students are attracted to high-paying new growth industries. Computer and Internet companies are stripping the aerospace industry of skilled personnel with information technology experience. We are very concerned about this issue and look to NASA leadership to make a course correction for the future.

CONCLUSIONS

- We recommend the establishment of a National Aviation R&T initiative to develop an action plan to define the research and development programs and resources required to ensure sustained U.S. world leadership in civil and military aviation.
- The decline of U.S. global market share in air transportation products and services over the past two decades, combined with European determination to become

the dominant supplier of such products and services within the next two decades, should be of major concern to U.S. policy makers.

- U.S. aviation industry competitiveness and the balance of trade must not suffer due to lack of federal support for the historically proven government-industry partnership in appropriate advanced aeronautics research that has continually produced a positive trade balance for the nation.
- Research in aviation safety must be a NASA priority.
- The national aeronautics Research and Technology (R&T) infrastructure has deteriorated and needs to be reestablished.
- NASA must continue to be a critical factor in the support of University-level aerospace education and R&D.
- The question of adequate funding for NASA and DOD aviation R&T must be addressed, not only with respect to the FY 2002 budget, but also—and even more significantly—with respect to the preservation of U.S. capability and leadership in long term aeronautics research and technology, as required by law.
- It is essential that the aeronautics R&T programs at the key mission agencies (NASA, DOD and FAA) be clearly identified and adequately funded within the "Aerospace Research and Technology." category.
- We strongly urge that the duties of the congressionally authorized Commission on the Future of the U.S. Aerospace Industry be broadened to include intensive consideration of NASA and DOD research in aviation.

As we approach the centennial of the Wright Brothers' first flight, it is more important than ever that America renews her national commitment to leadership in aviation. In order to do so, we must ensure the strength and stability of the nation's aviation infrastructure by formulating and committing to a national aviation research and technology policy that incorporates adequate federal funding for long-term aviation research.

This concludes our statement. Thank you for providing us with an opportunity to present our views at this important hearing.

Prepared Statement of Hon. John W. Douglass, President, Aerospace Industries Association of America, Inc.

Chairman Allen, Sen. Breaux, and Members of the Subcommittee, I appreciate the opportunity to submit my testimony on behalf of the Aerospace Industries Association of America to assist you as you investigate the NASA's aeronautics programs. As you know, AIA is the trade association representing the nations leading manufacturers of aviation and space products.

Mr. Chairman, the aerospace industry, the crown jewel of heavy manufacturing in the United States, is being seriously challenged by overseas competition. This important sector of our economy directly provides nearly 800,000 jobs for American workers, is the number one net positive contributor to the nation's international balance of payments, and produces the advanced weapons needed to defend our country. It is the backbone of our industrial base.

The world's most advanced technology, in the hands of skilled American workers, has allowed the U.S. aerospace industry to develop and produce high quality, affordable products and services and has been the key to the industry's enduring strength. Our national investment in aerospace research and development has provided the technology, which in-turn has fueled the dramatic accomplishments of the aerospace industry during the first century of manned flight. It has enabled the industry to remain the world's leading producer in the face of stiffening global competition. It has produced a highly potent military air force, a world class aviation transportation system, and the world's most sophisticated space related capabilities.

Over the past decade there has been a dramatic decline in investment in aerospace research and development spending. The aerospace share of national research and development investment has declined from a high of 25% in 1987 to below 6.4% in 1998, and is still declining. There are critical technologies that are not being pursued because of inadequate funding, such as hypersonics, supersonic combustion ramjets, and ultra-light ultra-strength materials that could provide the next breakthrough benefiting both military and commercial sectors.

The toll of this decline is beginning to show. Reduced investment in aerospace research and development has already caused talent to leave the industry. During the past 2 years, there has been a 30% decline in the scientists and engineers addressing aerospace challenges—the lowest level recorded since the early days of the industry. Fresh talent is harder to recruit. Over the past 7 years, the number of recent college graduates (ages 25 to 34) employed in the industry has fallen from 27% to 17% of the workforce. Innovation is, no doubt, suffering. Masked by record sales, the U.S. aerospace industry's competitiveness is also suffering. The industry's share of global sales has fallen from 72% in 1985 to 52.4% in 1999.

It is time for the nation to turn its attention to this growing problem. Unless the federal government, in partnership with the aerospace industry, increases and sustains a robust investment in aerospace research and development, we can expect to see our international leadership further challenged and the margin of our military superiority narrowed. Strong investment in aerospace research and development is critical to the nation's national security, economic well being and international competitiveness.

EXAMPLES OF LEADING EDGE TECHNOLOGY

As the National Research Council noted last year in its report, *Recent Trends in U.S. Aeronautics Research and Technology*, aeronautics is a research and technology intensive enterprise. Today you are receiving a broad overview of the potential for the U.S. aeronautics industry to continue in its historic leadership role in aviation. In my statement today I would like to focus on a few leading edge technological areas that are being addressed by NASA, the FAA, the Defense Department and other government agencies in cooperation with industry. I want to emphasize that these examples, while important, *merely scratch the surface* of the vital aviation research and development needs of the aviation industry.

Environment

Aircraft noise and engine emissions are among the greatest challenges that we face as an industry. The public rightly expects our industry to act responsibly and act aggressively in minimizing the effects of aviation on the environment. We will have to meet this challenge if the industry is to have a healthy and growing future. One important program underway is the Ultra Efficient Engine Technology Program (UEET). This program points toward a future with lower total engine emissions, thus reducing production of greenhouse gasses in flight and reducing smog producing nitrogen oxides emissions around airports. Additional improvements will be achieved by developments in combustor technology. UEET funding was originally envisioned at a level of $50 million in FY '01, but that has been reduced in the Administration's proposed FY '01 budget to only $35 million. We believe that $100 million is required. Programs are also underway in search of additional improvements in aircraft noise reduction technologies. This involves engine noise as well as airframe noise.

Breakthrough technologies to achieve significant reductions in aircraft noise and emissions will enable the industry to meet increased demand with minimal impact on noise and environmentally sensitive areas, while also lowering direct operating costs for the airlines by reducing fuel burn.

Synthetic Vision

Another area of significant work is the development of synthetic vision. This will enable a pilot to fly in instrument conditions or darkness but look out of the cockpit onto a virtual skyscape that she would see if it were a sunny day. Virtual skyways superimposed on this skyscape will provide a visual flightpath that the pilot can follow to avoid other aircraft, ground obstacles, etc. This will provide significant safety improvements in the areas of controlled flight into terrain and approach and landing, which today are major accident categories. In addition, synthetic vision will contribute to more efficient airspace utilization in connection with aircraft separation minima. On the ground, synthetic vision will enable the pilot to know his precise location intuitively, thus providing a significant safety enhancement by reducing the potential for runway incursions. The risk of an incursion resulting in an accident will be further reduced because the pilot will also be able to "see" and avoid other airplanes and vehicles on the ground.

Turbulence

The leading cause of serious injury among cabin crews is turbulence. Today, there is no technology available that enables us to detect turbulence in clear air. We are convinced of the need for continued significant research efforts aimed at discovering a means to detect clear air turbulence and provide sufficient warning for the crew to secure the cabin before aircraft encounters the turbulence. This is a significant safety issue. A related issue is wake vortex detection and amelioration. Wake vortices are like horizontal mini-tornadoes that stream off the wing tips as the aircraft moves through the air. They have been known to flip a following airplane on its back, sometimes with catastrophic results if the encounter is too close to the ground to permit recovery. Research in this area involves two efforts. Like other kinds of turbulence, wake vortices are easy to see if, for example, the airplane flies through smoke which is set in motion by the vortex. But in clear air they cannot be seen. Thus, detection is important in order to establish safe procedures for following aircraft, especially on approach to the airport. Another intriguing possibility is the development of a means to counter the formation of the vortex at its origin. If wake vortices could be eliminated or significantly reduced in strength, then aviation safety could be improved and airport capacity could be increased using existing runways because the aircraft separation minima could be safely reduced, permitting more flights per hour onto a given runway.

Human Factors Research

There are major efforts underway at NASA, the FAA and the Department of Defense on the broad area of human factors research. Broadly speaking, these can be divided into areas such as man-machine interface on the flight deck, how humans behave in the maintenance and repair environment, decision-making, crew interaction, etc. Human factors research addresses two questions. First, how can we reduce human errors? Second, since we cannot eliminate all human error, how can we design, produce and maintain systems that will tolerate errors without resulting in an accident? Much work remains to be done in understanding these human interactions. We are working to develop ways to detect errors, analyze them, and identify strategies to reduce their occurrence and effect. This effort is critical to this government/industry partnership effort to improve safety in both general and commercial aviation. In addition, greater understanding in this arena will give us improved operational procedures that will result in greater efficiency.

Non-Destructive Testing and Inspection

Over the years, there have been accidents that could have been avoided if the warning signs of existing physical problems could have been seen. Examples include engine disk failure and airframe structural failure. There are programs in place to develop new and improved techniques to perform tests and inspections to reveal these physical flaws without causing damage to the area being examined. Aspects under development include new hardware, as well as looking at the human dimension to address human factors such as boredom or fatigue that could lead a technician to miss a problem. New efforts are underway in areas such as wiring and electrical components, looking for ways to inspect in non-accessible areas where the very act of removal of wire bundles for inspection could cause damage and more problems that otherwise would not exist. These efforts in non-destructive test and inspection are leading to further improvements in aviation safety, as well as better system reliability and a reduction in unnecessary repairs.

Rotorcraft Technology Program

Runway independent aircraft, such as helicopters and tiltrotors, offer great potential for improving air system capacity and reducing congestion and delays -particularly in the case of stage lengths of 300 miles or less.

WE ARE IN DANGER OF LOSING OUR R&D EDGE

As I emphasized in my opening remarks, we are at a critical point regarding the long-term health of the aviation industry in the United States. This is an industry that depends upon knowledge to maintain its competitive edge. Knowledge, of course, is ever changing. It is impossible to maintain that edge by restricting the flow of knowledge. It is only possible to maintain our leading edge by continuing to invest in a robust and comprehensive research and development program that enables our industry to develop new technologies and bring them to market before our competitors. It is a challenge without end.

Yet we are putting U.S. aeronautical leadership at risk by our miserly treatment of aviation, and indeed aerospace, R&D at a time of growing budget surpluses. For example, there is not enough money in many NASA Aeronautics programs to produce technology demonstrators, which means there is no bridge between technology development and technology insertion. In some programs there is not enough money to ensure contractor participation, which is also necessary to bridge technology development and technology insertion. Infrastructure is aging. Our companies frequently must go abroad to conduct wind tunnel testing.

Bit by bit, we as a nation have allowed our commitment to a robust technological research base in aeronautics to erode. Our workforce is an example. It is becoming increasingly difficult to attract and retain the best talent in aeronautics. To young people who are making career choices and want challenge and excitement, our industry increasingly is seen as old hat. So today we stand at a crossroads. In the report I cited at the beginning of my statement, the National Science and Technology Council warned that decisions are being made "without an adequate understanding of the long-term consequences." The committee went on to recommend that "the federal government (should) analyze the national security and economic implications of reduced aeronautics R&T funding before the nation discovers that reductions in R&T have inadvertently done severe, long-term damage to its aeronautics interests."

Today you are hearing about the exciting opportunities that lie ahead of us if we as a nation make a decision to reinvest in research and development, the seed corn of this industry; if we as a nation make a decision to attack the hard technological problems, looking for the breakthroughs and providing the competitive and challenging environment that attracts the young engineers and scientists; if we as a nation make a decision that we will maintain our preeminent position as the world's greatest manufacturing and exporting industry. For make no mistake about it, our trading partners and competitors recognize the potential of aerospace to contribute to their national well being, and have made investments accordingly. Today, our future and that of our children is in our own hands. There is still time to rebuild our aviation and space research and development capability to become again the standard against which all others measure themselves. But not a lot of time. We must seize the opportunity now, or we shall surely regret it tomorrow.

RESPONSES TO WRITTEN QUESTIONS SUBMITTED BY HON. GEORGE ALLEN TO DANIEL S. GOLDIN

Question 1. You have mentioned that NASA will reduce the design cycle time from its current 9-plus years to 3 or 4 years, while increasing the quality of design. Can you elaborate on the key aspects of this reduction program and overall impact to the aeronautical industry?

Answer. We are making great strides in our ongoing program to reduce design and analysis time. For example, based on detailed industry assessments, the NASA developed National Propulsion System Simulation (NPSS) capability cuts more than 50% off propulsion simulation time over the life cycle of an engine. Similar accomplishments have been achieved in control systems, aerodynamics and structures. And we will continue to increase the fidelity and efficiency of these tools.

But we are also embarking on a new effort in engineering for complex systems to dramatically increase our understanding of integrated system complexity and risk very early in the design cycle. Much of the current time and resources in product development is to manage risk. A number of iterative design cycles are planned in advance to systematically increase the fidelity of the system model and to drive out risk over time. However, aerospace systems are extremely complex and often risks are not adequately understood until late in development, adding significant time and cost. Therefore, we are beginning an effort to pioneer new tools that will allow us to more fully understand aerospace system complexity in the context of its environment and mission. This complex system modeling capability will integrate discipline-based computational tools to achieve a high-fidelity understanding of the total system and more precisely identify risk. The goals are to fully simulate the system performing its mission in its environment over the life cycle of the system.

This capability applied to NASA missions will allow us to better manage complex, one-of-a-kind systems and increase our success rate. For industry, such a capability will allow reduced cycle time and numbers of design cycles for new systems, leading to dramatically improved responsiveness to market, transportation and military requirements.

Question 2. You mentioned in your written testimony that about 7 percent of each dollar collected by the domestic airlines or about $4.5 billion per year is due to delays. You further state that this amount is expected to increase to about $13.8 billion by 2007. Can we expect a similar increase in the percentage of "each dollar collected" due to delays?

Answer. As we get closer to the capacity limits of the system, delays rise rapidly. Left unchecked, delays will increase much faster than demand growth. So, while demand will somewhat less than double from the 1998 baseline referenced in the testimony, delays will triple. Therefore, we would expect delay as a percentage of airline or traveler cost to increase significantly. Fortunately, the FAA's Operational Evolution Plan (OEP), to which NASA is contributing key technologies, will mitigate some of this delay increase. However, most experts agree that the OEP alone will not fix the problem, nor will it eliminate the already substantial delays. The bottom line is that serious inefficiencies that effect our economy and quality of life continue to grow unless more action is taken over the long-term.

Question 3. There have always been questions about the role of the federal government in basic R&D. What specific advantages does NASA have in conducting experimental research that private companies do not have?

Answer. There are two fundamental reasons for federal investment. First, markets tend to force under-investment in long-term research. Market forces for near-term performance on investment makes it difficult to for private firms to invest in long-term research. This is especially problematic in fields such as aerospace that have very long horizons that often create a difficult investment environment for even evolutionary product development. Another factor in this regard is the difficulty in fully capturing the benefits of basic research. This is generally known to as "appropriability" and refers to the difficulty in economically "appropriating" the benefits of the widely available nature of basic research findings. Other firms can often take advantage of research performed by a single firm, putting the investing firm at a disadvantage. Additionally, the market does not fully price "externalities" such as noise and emissions impacts. In other words, there is a social cost associated with noise and emissions, but since there is no natural market mechanism for including those costs the socially optimal level of investment will not be achieved. Regulation is often the policy mechanism for forcing these costs on the market. However, in aviation, which is characterized by complexity, long horizons and exacting safety standards, regulation is often difficult in the absence of an established technology base.

Second, there are distinct federal government roles in aerospace. For example, the operation of the National Airspace System, the provision of National defense and the operation of the civil space program. Because the federal government takes such a strong role in the aerospace sector, maintaining a healthy research program is of critical importance. Additionally, for purposes of efficiency, to reduce barriers to entry and to ensure long-term industry viability, the federal government has provided some of the large, common facilities, such as wind tunnels, that are necessary in aerospace. NASA's Aerospace Technology Enterprise serves as a National asset in providing long-range technology development and world-class capabilities that cut across many applications in aerospace. This capability has been brought to bear in the solution of many urgent and difficult problems. For example, the F-18 E/F was in jeopardy of being canceled due to the difficulty posed by severe uncommanded aircraft maneuvers caused by massive separated flow over the wing until our engineers devised a porous fairing that acted as an "air dam" and prevented the problem.

NASA has the breadth of capability and long-term outlook to address these issues. NASA programs focus on R&T areas most subject to under-investment in industry—basic research, applied research and technology validation. The total cost of aerospace research and technology is lower by having National assets available to all industry. And because of differing incentives, NASA can be more patient and accept more risk in awaiting payoffs from R&T investments.

Question 4. Can you elaborate on NASA's role in performing revolutionary versus evolutionary aeronautical research? How do you distinguish between the two?

Answer. We refer to evolutionary research as research that is targeted at providing incremental improvements to current, state-of-the-art aerospace systems. NASA's role in evolutionary research is to focus on the long-term public good issues where there is insufficient industry incentive, as articulated in the response to the previous question. For example, issues of safety, noise, emissions, and capacity would be included. NASA's job is to drive the state-of-the-art faster and farther than would otherwise occur and ensure a National capability in these areas. Priorities are generated based on the criticality of the issues, especially in the face of growth and development. For example, NASA has placed significant priority on the partnership with the FAA to improve airspace operations due to the current and increasing severity of delays.

Revolutionary research is focused on enabling totally new ways of performing aerospace missions, enabling new missions that have not been reasonable or possible in the past, and enabling new functionality for aerospace systems. For example, automated, vehicle self-separation of aircraft within the National Airspace System would be a new approach to performing the air traffic management mission that is not an incremental change to the current system. Another example is a spacecraft that has some ability to self-repair structural damage. This is a new functionality that does not exist today, but that could significantly improve the resiliency and reliability of spacecraft. NASA's role in revolutionary research is to provide pioneering leadership for the Nation. In most cases, existing operational organizations are resistant to such ideas and therefore reluctant to make the necessary investments. Therefore, NASA has a primary responsibility to fill this critical role in aerospace.

Question 5. What can NASA do to further assist in increasing the supply of engineers and scientists that will be needed for this new vision for aeronautical research?

Answer. NASA has traditionally had a significant role in supporting the development of the next generation of scientists and engineers. As we look to the future, we see a unique period of discovery during which we can match traditional disciplinary strengths with emerging technology areas, such as nano-technology and biologically-inspired technologies, to produce a new era in aerospace. But to make this happen we need to both inspire a new generation of technologists and then train them in new multi-disciplinary fields. Therefore, NASA is moving out on a new partnership with academia to create Research, Education and Technology Institutes (RETIs). The goal of this new university partnership is to strengthen NASA's ties to the academic community through long-term sustained investment in areas of innovative and long-range technology critical to NASA's future. The RETIs will also enhance and broaden the capabilities of the nation's universities to meet the needs of NASA science and technology programs. These RETIs will be focused on new technology areas such as biotechnology, nanotechnology and information technology, with a focus on aerospace applications in materials, structures, aeropropulsion, computing and power.

Question 6. What do you see as challenges to U.S. aeronautics research? What can Congress do to ensure continued American leadership in the aeronautics R&D?

Answer. As I indicated in my written testimony, aviation has gone through significant changes and faces serious problems. Breaking through barriers posed by capacity constraints, environmental issues or the need for greater mobility will ultimately not be solved by incremental change to current systems. New business and operational models built upon advanced concepts and technologies are required. The challenge to U.S. aeronautics research is to lead this transition. This will require that we integrate across traditional "stove-piped" discipline areas; that we embrace new technology pathways; and that we foster strong leadership to develop the new concepts that can meet the transportation needs of a new century. I would encourage Congress to lead the way by getting involved in the debate and demand that all of us with responsibility for aeronautics research and aviation to not accept limitations and barriers that could negatively impact our Nation.

RESPONSES TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO DANIEL S. GOLDIN

Question 1. Measured both by market share and technological benchmarks (speed, emissions. noise). Has the competitive position of the U.S. aerospace industry increased or decreased over the past decade?

Answer. The European Community has achieved parity with the United States in market share. The most visible aspect of this competition is between Boeing and Airbus in the civil transport market. Airbus has achieved a full family of technologically advanced civil transports that rival Boeing's products. Future dominance of the industry could very well be decided by the success of the very different strategies being pursued by the two companies. Airbus is developing a very large civil transport, the A380 that would emphasize the use of very large transports between large hubs on international routes. Boeing's Sonic Cruiser emphasizes speed and frequency to an increasing number of domestic and international destinations. Given the exceedingly high development costs for these vehicles, their relative success could very well dictate market dominance for the foreseeable future. This outcome will likely have ripple effects across the aerospace sector, including military aviation and space launch systems, as the civil transport segment is the dominant element of the aerospace market.

Question 2. Have foreign government subsidies to their aircraft industries been increasing or decreasing in the past decade, and has that affected foreign aerospace companies competitiveness vis a vis the U.S. aerospace industry?

Answer. NASA does not track government subsidies and therefore does not have the data to answer this question specifically. However, it is well established and documented through international agreements that other governments do support their aerospace industries with direct R&D and product subsidies. The major effect of such subsidies is to reduce the cost and risk for product development, leading to technology insertion at lower cost than would otherwise be possible through the market. However, the long-term effects of such subsidies could be detrimental to a foreign economy if government investments were made in non-competitive technologies or propped up non-competitive enterprises.

Question 3. Over the past 20 years what has been the trendline in NASA aeronautics budget as a percentage of global aeronautics R&D spending'?

Answer. NASA does not track global aeronautics R&D spending and therefore does not have the data to answer this question specifically. However, a recent study by the National Academy of Engineering documented NASA's as well as military and industrial aeronautics spending over the past decade. Based on this report, industrial and military aeronautics R&D spending have declined continuously for the past decade. Over the past 20 years, NASA's aeronautics funding, in terms of inflation-adjusted dollars, has remained level. NASA aeronautics funding significantly increased in the early 1990s but has since returned to levels ($5–$600 million per year) consistent with annual spending levels for NASA aeronautics since the early 1970s when adjusted for inflation.

Question 4. The President's 2002 budget proposal calls for terminating certain aeronautics programs that had previously been deemed worthy of funding. Do these cuts reflect a new perception of the worthiness of these programs or are these programs that, while potentially promising, simply cannot be funded within existing budgetary limitations?

Answer. The Administration cancelled the Rotorcraft Program at NASA because it is not a high civil aeronautics research priority and because the Department of Defense should fund military aircraft research.

NASA has an ongoing program, the Aviation System Capacity Program (funded at $101 million in the President's FY 2002 Budget, a 47 percent increase over FY 2001), to develop technologies that could help alleviate congestion and crowding in the Nation's airports. NASA has regularly reviewed the potential for various technology investments to address these congestion and crowding issues. In the current aviation system environment with its critical capacity issues, NASA has ranked other technology investments higher than investments in rotorcraft.

Question 5. How great a threat does declining student interest in aerospace engineering programs pose to the health of the U.S. aerospace industry, and what measures if any does NASA's aeronautics program include to address that problem'?

Answer. Over the long-term, the greatest threat to the future of the aerospace industry is the potential lack of appropriate expertise. Fewer defense and commercial research and development projects and reduced enrollments at universities could lead to future design teams that lack the experience of today's engineers. Leadership is required to reverse this trend. We, in partnership with the academic community, must begin developing a new generation of scientists and engineers that blend traditional competencies, such as aerodynamics, material and structures, and guidance and controls, with the emerging competencies in nanotechnology, biotechnology and information technology. We must also develop the design tools and environments that will allow us to integrate fewer and more specialized scientists and engineers into effective teams capable of designing highly complex integrated aerospace systems. NASA is in the process of awarding new University Research, Engineering and Technology Institutes (URETI) to increase our University partnerships and focus them on the critical skills needed for the future of aerospace.

RESPONSES TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO ROY V. HARRIS, JR.

Question 1. As a former Director for Aeronautics at Langley, how has the Center improved its research over the years?

Answer. There are three elements to maintaining excellence in any aeronautical research organization: The first is to attract, retain and motivate a well qualified research staff of scientists, engineers and technicians; the second is to acquire and maintain world-class test facilities, laboratories and computational tools; and the third is to have leading-edge research programs that encompass all of the relevant disciplines and vehicle classes. During my tenure as Director for Aeronautics, we tried to focus on all of these elements.

Langley is the only NASA Center that covers all of the aeronautical disciplines involved in airframe design (aerodynamics, controls, flight dynamics, structures, materials, propulsion integration, and flight systems), and we worked hard to coordinate our research with the other NASA Centers. We encouraged our researchers to publish their work in the major national technical journals and to attend technical conferences where they can present their work and interact with their peers in industry and the universities. We worked across the spectrum of vehicle classes from very low speed rotorcraft and general aviation aircraft, to long range transports, to high performance military aircraft, and to supersonic and hypersonic cruise vehicles. We maintained both formal and informal interactions with the ultimate industry users of our technology for planning, execution and evaluation of our programs and test operations.

In more recent times, however, the Aeronautics Centers have been severely limited, due to declining aeronautics budgets, in the ability to maintain their experimental facilities in world-class condition and to support adequate travel budgets for researchers to interact with their peers. Program funding has been reduced to the point that some important areas of research that are required to maintain future U.S. competitiveness have been eliminated.

Question 2. If additional funding for aeronautics at NASA were available, what areas would you recommend for investment?

Answer. First let me reiterate that we believe that, in order to regain U.S. world preeminence in aeronautics, it is necessary to double the aeronautics portion of NASA's budget over the next 4 years from about $730 million in FY 01 to about $1,400 million in FY 05. To accomplish this we recommended, in my written testimony, that the NASA aeronautics budget be increased by $155 million a year over the 4-year period. This would result in a recommended FY 02 budget for aeronautics of $885 million.

Contrary to this, the Bush FY 02 budget proposes significant reductions from the FY 01 aeronautics budget that could result in funding being reduced to about $570 million, or to about one-half of the FY 98 budget and some $315 million below our recommended level. It should be noted that this estimate is based on my own analysis of the FY 02 budget proposal. NASA no longer has a line item in its budget for aeronautics, making it very difficult for Congress and the public to determine how much (or how little) is being spent in this very important area.

The most critical needs in FY 02 are for two programs the administration proposes to eliminate, and for several important research efforts that are not now funded at all. These programs, along with the recommended level of FY 02 funding are as follows:

Restore FY 02 Proposed Cuts
Rotorcraft Research—$32.0 million
Advanced Aircraft Program (specific, classified military effort)—$27.0 million
Top Priority Augmentations to FY 02 Budget
Supersonic Transport Research—$40.0 million
High Performance Military Aircraft Research—$20.0 million
Test Facility Upgrades & Operations—$50.0 million
University Centers of Excellence—$40.0 million

The Aviation System Capacity program, the Aviation Safety program, and the Small Aircraft Transportation System program are all well funded in the FY 02 budget. In addition, significant funding is provided for Noise and Emissions research. Although these programs need to continue to grow over the next 3 years to almost twice their current funding, no additional funds are needed for these programs in the coming fiscal year.

It should also be noted that NASA has proposed a smaller ($4.0 million) university program called Research, Education, and Training Institutes in FY 02. However, we believe that the problem of bringing on new talent to replenish the depth of expertise that has been lost at the Aeronautics Centers is so critical that it needs to be larger by an order of magnitude.

Question 3. Do you have any thoughts on having industry invest in upgrades to government-owned aeronautical research facilities?

Answer. It has been accepted U.S. policy for the past 86 years, that long-term, high-risk aeronautical research for civil and military aviation is a government responsibility. The government investment in this research and the required experimental facilities has paid off handsomely to our economy, to national defense, and to the quality of life of all Americans. Although we believe that the government has an obligation to maintain its primary aeronautical facilities in world class condition, we see no objection to having industry invest in upgrades to government owned research facilities.

Industry has, in fact, done this in the past at fairly modest levels of funding. One example from a few years ago involved the Low Turbulence Pressure Tunnel at the Langley Research Center. A private company paid over $1 million to install a suction system in the tunnel to facilitate a test in which they had an interest. The addition of the suction system greatly improved the capability of the tunnel, and after the test, they gave the equipment to NASA. It is also not uncommon for industry to build test models for specific tests in NASA wind tunnels at a cost of $1 million to $2 million and, after the test, make the models available at no cost to NASA for use in NASA research programs.

Question 4. Measured both by market share and technological benchmarks (speed, emissions, noise), has the competitive position of the U.S. aerospace industry increased or decreased over the past decade?

Answer. It is clear that we have lost ground in terms of civil aircraft market share. A decade ago the U.S. had about 70% of the world market in commercial aircraft sales. Today our share has dropped to about 50%, and some experts project that it will reach as low as 30% in the foreseeable future. This drop in U.S. market share is indicative of the fact that foreign-built aircraft have become more competitive in their performance parameters such as speed, fuel efficiency, emissions, and noise.

The U.S. is still producing the best military aircraft in the world. However, this is a result of the substantial investments in research that were made a decade or more ago. The competitiveness of our future military aircraft will depend on the research that we are doing today. The quality of our future military aircraft will certainly be compromised if we continue to reduce our national investments in military aviation research. Both NASA and DOD play vital roles in developing advanced technology for future high-performance military aircraft.

Question 5. Have foreign government subsidies to their aircraft industries been increasing or decreasing in the past decade, and has that affected foreign aerospace companies competitiveness vis a vis the U. S. aerospace industry?

Answer. We are certain that government subsidies in the early days helped our major European competitor, Airbus Industrie, establish itself in the world commercial aircraft market. We cannot say whether the subsidy has increased or decreased over the past decade, since access to this kind of data is not available. There have been reports in the press that the European governments are considering phasing out the subsidies to Airbus now that they have gained an equal market share with Boeing. We believe that their market success, however, is due to the fact that they now can produce very good aircraft at competitive prices, with or without a subsidy.

Question 6. Over the past 20 years, what has been the trendline in NASA aeronautics budget as a percentage of global aeronautics R&D spending?

Answer. It is impossible to give a precise answer to this question since the amount of global aeronautics R&D spending is really an unknown. However we know that NASA's aeronautics budget did increase, in terms of 2001 dollars, over the period from the mid-1980s until 1994 and remained about constant through 1998. It took a precipitous decline in 1999 and 2000 to a value of about ⅔ of its 1998 level. During this period of declining NASA funding, our European competitors and the Japanese have been increasing their investment in aeronautics R&D. The European Commission has now announced a new plan to significantly further increase their government funding for aeronautics research. They estimate that the total funding, public and private, could exceed 100 billion Euros (about $95 billion) over the next 20 years. In spite of this, the Bush Administration is proposing additional significant reductions to NASA's aeronautics research budget in Fiscal 2002.

Question 7. The President's 2002 budget proposal calls for terminating certain aeronautics programs that had previously been deemed worthy of funding. Do these cuts reflect a new perception of the worthiness of these programs, or are these programs that, while potentially promising, simply cannot be funded within existing budgetary limitations?

Answer. These programs are very important to the competitiveness of the U.S. aeronautics industry and should not be terminated. Rotorcraft, for example, are essential for almost all military operations and are extensively utilized for civilian medical evacuations and for search and rescue. Tiltrotor technology has the potential to off-load commuter aircraft from the runways of our hub airports and significantly increase the capacity of these already over-crowded airports. The Advanced Aircraft Program is a very productive, classified NASA/DOD cooperative program that has and continues to produce new innovations for military aviation technology. It is our opinion that these terminations are the result of a continuing de-emphasis on aeronautics within a fixed overall NASA budget that is stressed by program failures and cost overruns within the space program.

Question 8. How great a threat does declining student interest in aerospace engineering programs pose to the health of the U.S. aerospace industry, and what measures if any does NASA's aeronautics program include to address that problem?

Answer. NASA, DOD and Industry depend on American universities to provide creative, skilled engineers and scientists as a critical resource for maintaining U.S. preeminence in civil and military aeronautics. Yet the recent de-emphasis on long-term aeronautical research in both NASA and DOD has significantly impaired our universities' ability to maintain vibrant aeronautical engineering programs. As a result, students are attracted to other areas of study and the nation is experiencing a diminishing pipeline of qualified aeronautical engineering students at both the undergraduate and graduate levels. The problem is a serious one that could have grave consequences to our future competitiveness in both civil and military aviation.

As stated earlier, in answer to a previous question, NASA has proposed a $4.0 million university program called Research, Education, and Training Institutes in its FY 02 budget request. We believe that the problem in the U.S. universities is so great, and the problem of bringing on new talent to replenish the depth of expertise that has been lost at the NASA Aeronautics Centers is so critical, that the program needs to be larger by an order of magnitude.

RESPONSES TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO DENNIS DEEL

Question 1. Can you give some specific examples of how Lockheed, as a defense contractor, has utilized the research at Langley for national security purposes?

Answer. Heritage Lockheed Martin Corporation (LMC) companies and NASA Langley Research Center (LaRC) have been technology development partners for more than 25 years—working together to enhance the survivability of military aircraft. This relationship started in the late 1970s and early 1980s when Ben Rich, the then Head of the Lockheed "Skunk Works", approached Roy Harris and asked that NASA work with Lockheed to develop technologies that have now enabled or improved aircraft developed or fielded by Lockheed Martin. These include the F-117 Nighthawk and the F-22 Raptor. These technologies are products of the NASA Advanced Aircraft Program (AAP) and many were key "firsts" delivered by the LaRC AAP team. While the details of these efforts are classified, both partners brought their best assets to the table: people, facilities and dollars. Only in the past 10 years have these collaborations taken on more formal terms. The NASA LaRC Advanced Aircraft Program (AAP) team continues to work very closely with the Lockheed Martin Aeronautics—Palmdale. The focus is on high-risk, high-payoff research to enable superior survivability. Continuation of programs like AAP is critical to maintaining our military's technological superiority. Also looking to the future, NASA LaRC and LMC are teamed on the Revolutionary Concepts in Aeronautics (RevCon) Smart Vehicle Phase I Project where we will take 4–5 control effector concepts to flight validation. These concepts have all been screened by the LaRC/LMC team to ensure they enable a survivable solution—one which delivers the desired aerodynamic performance while not compromising the survivability aspects necessary for proposed advanced military aircraft. LMC has made extensive use of LaRC facilities (Compact Radar Range, materials labs and wind tunnels). In many cases, initial empirical data has been obtained in the LaRC facilities. At one point in the 1980s LMC products were undergoing tests in the National Transonic Facility (NTF), Full Scale, 12 Foot, Pilot Compact Radar Range, as well as several other smaller facilities—simultaneously. The high-speed supercruise capability and excellent low/high speed maneuverability of the F-22 are founded on the groundwork laid by LaRC in Propulsion/Airframe Integration research into 2-D nozzle installations and in-flight thrust vectoring. We are currently evaluating engine nacelle installation options for the potential re-engining of the C-5 Galaxy with NASA. As we continue to develop the Joint Strike Fighter, NASA's various wind tunnels and flight simulation facilities are invaluable.

Question 2. A former NASA Administrator has said that the lack of attention to NASA's aeronautics funding is due to the fact that the country can postpone investment in R&D without suffering any ill effects for a decade or so. Would you please comment on the veracity of this statement? What effects do you believe will result from the decline in NASA's basic aeronautic research?

Answer. There has been a great deal of print recently dedicated to the concept of "skipping a generation" of technology in military systems—that we can use this time of apparent peace and stability to that end. But, that revolutionary technology must still be developed. The NASA LaRC AAP team's primary charter is to work high-risk, high-payoff challenging research. Much of this work entails developing the basic physical insight to phenomena to then developing a technical approach to a solution. This process takes years and the products are generally not implemented until years later. Many of the new breakthroughs (and they truly have been enabling) have not been fielded or demonstrated any earlier than 10 years—so any ill effects of not pursuing an idea or solution is not felt for a decade or more. At that point, we could face at least 10 years of catching up to other nations, especially in having to rebuild the infrastructure systems sufficient to allow research at the same prior levels. The implosion in the aerospace industry and the budget challenges in the space segment of NASA have contributed to the near term focus in aeronautics research. We could surmise that this trend is the reason for the technological gain of aerospace competitors like Airbus. In simple terms—we've stopped planting the seed corn.

Question 3. You have mentioned Langley's unique test facilities in your statement. There was some discussion a few years ago of combining some of these facilities with other Defense facilities. In your opinion, do you believe this would be a prudent decision?

Answer. NASA Langley unique facilities, such as the National Transonic Facility (NTF), Transonic Dynamics Facility (TDT), and Spin Tunnel, by definition of uniqueness, can't be combined with counterparts since there are no others like them. The one possible exception is the Spin Tunnel. The U.S. Air Force has a similar facility, but the technical expertise to utilize the facility resides at LaRC. There is a similar facility in Europe, but since the majority of the testing in the Spin Tunnel has national security implications, it seems prudent that the U.S. not to lose this capability. NASA and DOD are considering combining some facilities that are not unique and that is appropriate.

Question 4. Your testimony highlights a number of important military programs from the F-22 Raptor to the most recent version of the C-130 that have benefited from Lockheed's cooperation with both NASA and the Department of Defense. How have cutbacks in NASA's aeronautics research budget affected this partnership?

Answer. NASA has certain obligatory commitments for its classified military funding. With a reduced research budget, the dollars remaining to pursue revolutionary challenges has dwindled to where they essentially do not exist. We have seen the non-dollar resources shrink as well. Many key researchers (in NASA and the aerospace industry) have retired, died, transferred or moved to other activities. The cost to operate and maintain real property and facilities has taken more and more of the limited budgets. All the while, facilities remain key assets, not to market for reimbursable dollars but as part of the toolbox needed to make discovery and find solutions. By the very nature of business motivation, industry will not do the basic research needed to enable revolutionary breakthroughs. For example, if we are to build self-repairing aerospace materials and structures, it will take the best minds in academia to understand the underlying principles, the best minds in NASA to develop the enabling technology, and the best minds in industry to apply and field that technology. This development chain is only as strong as the weakest link. NASA's ability to bring its research strength to bear has definitely suffered over the past several years.

Question 5. Measured both by market share and technological benchmarks (speed emissions, noise), has the competitive position of the U.S. aerospace industry increased or decreased over the past decade?

Answer. According to the Aerospace Industry Association (AIA), the U.S. commercial aerospace market share has significantly declined. As for military applications, it is superior capability that counts. The discovery and maturation of enabling technologies and advanced processes and materials have given the U.S. the historical edge. Unfortunately, superiority must be maintained and the competition is not standing still. An illustration—our F-22, C-130J, and Joint Strike Fighter all make advantageous use of composite materials—used for superior strength and reduced weight. While we have fielded flaps and tail sections, Airbus has already built an entire aircraft wing made of these same materials. The next generation fighter plane might rely on self-repairing carbon nano-tube structure. The bottom line is that we must continue our technology development or fall behind.

Question 6. Have foreign government subsidies to their aircraft industries been increasing or decreasing in the past decade, and has that affected foreign aerospace companies competitiveness vis-a-vis the U.S. aerospace industry"?

Answer. Unfortunately, we do not have the data to definitely determine the foreign government subsidy trend. It is apparent, however, that in the case of Airbus Industries, the historical subsidy level has been significant. Perhaps the more important metric on the military side is the quality of foreign produced aircraft—more capable wins.

Question 7. Over the past 20 years, what has been the trendline in NASA aeronautics budget as a percentage of global aeronautics R&D spending?

Answer. Again, we do not have a good picture of the global spending trend, but we do know that NASA's aeronautics budget has been flat at best with a down trend nearer term. Showing some modest gains through the 1980s, from 1994 through 1998 the aeronautics budget remained relatively constant in real terms, but declined rapidly in 1999 and 2000 to approximately 2/3 of the 1998 level. It is significant to note that this is exactly the time that our European and Asian competitors increased their investment.

Question 8. The President's 2002 budget proposal calls for terminating certain aeronautics programs that had previously been deemed worthy of funding. Do these cuts reflect a new perception of the worthiness of these programs, or are these programs that, while potentially promising, simply cannot be funded within existing budgetary limitations?

Answer. While determining funding priorities (and hence programs) is an internal NASA responsibility, we are concerned about the overall level and health of basic aeronautics research. This research is the foundation for advances in the associated disciplines. Historically, the level base research has been directly proportional to the programs supported. In stands to reason that as the emphasis within NASA shifts away from aeronautics (as evidenced by program cancellation), so will the support for basic research.

Question 9. How great a threat does declining student interest in aerospace engineering programs pose to the health of the U.S. aerospace industry, and what measures if any does NASA's aeronautics program include to address that problem?

Answer. The lack of interested and qualified aerospace (and supporting discipline) graduates is a challenge for NASA and for the industry. Today's student weighs the prospects of a tough academic program against the salary and job security prospects in the aerospace industry and turns to other pursuits. Like NASA, we have relied on intern programs and rotational assignments to foster interest. NASA programs like the recently cancelled Intelligent Synthesis Environment (ISE) have historically been perfect vehicles for the collaborative work of academia, NASA, and industry. As the number and scope of programs diminish, so do the opportunities to reach inside the academic institutions.

○